The views expressed are those of the authors and do not necessarily represent the views of the Bank of Canada. An earlier version of this study was presented to the Working Group on Exchange Market Intervention established at the Versailles Summit of Heads of State and Government.

The authors retain sole responsibility for the content of the paper as well as for any changes from the earlier version presented to the Working Group.

A STUDY OF THE EFFICIENCY OF FOREIGN EXCHANGE MARKETS

David Longworth

Paul Boothe

Kevin Clinton

CONTENTS

Abstract		i
Preface		ii
CHAPTER 1	INTRODUCTION AND CONCLUSIONS	1
	1.1 What We Mean by Efficiency	1
	1.2 Our Empirical Studies	2
	1.3 Interpretation of the Results	4
	1.4 Implications for Policy	6
CHAPTER 2	SURVEY OF EXISTING EMPIRICAL EVIDENCE ON EXCHANGE MARKET EFFICIENCY	8
	2.1 Introduction	8
	2.2 Tests of Speculative Efficiency	9
	2.2(a) Descriptive statistics of forecast accuracy	9
	2.2(b) Regressions of the spot rate on the lagged forward rate	10
	2.2(c) Time series tests of the forecast error	12
	2.2(d) Tests of forecasts	13
	2.2(e) Profitability of trading rules	15
	2.2(f) Market inefficiency or risk premium?	16
CHAPTER 3	AN OUTLINE OF THE EMPIRICAL TESTS	18
	3.1 Introduction	18
	3.2 Statistical Tests Using Regression Equations	19
	3.3 A Simple Trading Rule	21
CHAPTER 4	EMPIRICAL RESULTS FOR THE CANADIAN DOLLAR/U.S. DOLLAR EXCHANGE RATE	24
	4.1 Introduction	24
	4.2 Regression Tests	24
	4.3 Regressions for Subperiods	31
	4.4 Profitability of a Simple Trading Rule	33
	4.5 Summary of the Chapter	37

CONTENTS
(continued)

CHAPTER 5	EMPIRICAL RESULTS FOR FIVE OTHER CURRENCIES	38
	5.1 Introduction	38
	5.2 Regression Tests for the Entire Period	38
	5.3 Regressions for Subperiods	42
	5.4 Profitability Using the Simple Trading Rule	46
	5.5 Summary of the Chapter	51
APPENDIX A	THE DATA	55
	A.1(a) Canadian dollar	55
	A.1(b) Other currencies	56
APPENDIX B	TRANSACTIONS COSTS IN THE PROFITABILITY EQUATIONS	60
APPENDIX C	SUBPERIOD RESULTS FOR THE CANADIAN DOLLAR	64
APPENDIX D	DETAILED RESULTS FOR THE FIVE REMAINING CURRENCIES: THE FRENCH FRANC, GERMAN MARK, ITALIAN LIRA, JAPANESE YEN AND THE U.K. POUND	69
APPENDIX E	INTERVENTION VARIABLES AND TESTS OF EFFICIENCY	84
APPENDIX F	AN INTUITIVE EXPLANATION OF THE DETERMINATION OF THE RISK PREMIUM	87
REFERENCES		89

ABSTRACT

The purpose of the research described in this study is to investigate the question of whether or not exchange markets are efficient. We define exchange markets to be efficient if participants take account of all available information when forming expectations about future exchange prices such that there are no systematic ex ante opportunities to earn above-normal profits. Because the forward price of foreign exchange is in general equal to the price expected in the future plus a risk premium, we tested the joint hypothesis known as the "speculative efficiency hypothesis" which states that: (i) markets are efficient; (ii) risk premiums are constant; and (iii) transactions costs are negligible. It should be noted that it is not possible to test condition (i) alone.

The weight of other published evidence as summarized in Chapter 2, as well as the research documented here lead us to reject the joint hypothesis. Our tests involved regression equations designed to determine if the restrictions on coefficients implied by speculative efficiency are valid empirically. We also performed out-of-sample and trading-rule tests to determine if there were any persistent opportunities to earn ex ante returns that were systematically ignored.

To our knowledge, no evidence has been published that can explain the refutation of the speculative efficiency hypothesis in terms of empirical currency risk variables. Brokerage costs in the markets involved are neither high enough nor variable enough to explain the refutation. Hence our inclination is to interpret the results as a refutation of the hypothesis of exchange market efficiency. Although we would not rule out the existence of time-varying risk premiums, as discussed in Chapter 2, we suggest that they alone do not seem responsible for all the observed systematic divergences between the spot rate and the lagged forward rate.

Regardless of the precise interpretation, the rejection of the joint hypothesis leaves open an a priori case for official exchange market intervention as a policy tool.

Note: This publication is available in both French and English.

PREFACE

An earlier version of this study was presented to the Working Group on Exchange Market Intervention established at the Versailles Summit of Heads of State and Government in June 1982. The Group was charged to look into the effectiveness and advisability of official intervention in foreign exchange markets as a tool of economic policy. As part of its contribution, Canada was asked by the Group to investigate the empirical evidence on exchange market efficiency.

The Report of the Working Group containing the major overall conclusions was published in March 1983.*

While each of us had significant input into all aspects of the study, Kevin Clinton was the primary author of Chapter 2 and David Longworth and Paul Boothe were the primary authors of Chapters 3, 4 and 5.

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The authors retain sole responsibility for the content of the study, including any changes from the version submitted to the Working Group.

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* Report of the Working Group on Exchange Market Intervention, March 1983.

CHAPTER 1
INTRODUCTION AND CONCLUSIONS

1.1 What We Mean by Efficiency

In this study we explore the question of whether or not exchange markets are efficient. Our concern is with efficiency in the specific technical sense that exchange rates fully reflect all available information. In an efficient market so defined, profit-maximizing behaviour by participants would ensure that there should be no way for a trader to use available information systematically in order to make above-normal profits.

The market clearly does eliminate rapidly any risk-free gains available through covered arbitrage, and covered interest parity between comparable assets denominated in different currencies holds very precisely.[1] However, this is not a sufficient condition for an efficient exchange market, since it says nothing about the existence of unexploited excess returns to speculation. In an efficient market, speculators should not be able, on average, to produce over time a better forecast of the future price than that embodied in the forward price.

This concept leads to the "speculative efficiency hypothesis"[2] which says that the forward rate itself is the best forecast of the future spot rate. At the outset, it must be emphasized that rejection of the speculative efficiency hypothesis does not logically imply rejection of the market efficiency hypothesis since the expected spot rate can differ from the forward rate because of transactions costs or because of risk premiums. Currencies deemed to be risky will carry a forward exchange value that is less than their expected spot value, the difference representing the expected return for risk-bearing. Rejection of the hypothesis of speculative efficiency is actually the rejection of a joint hypothesis of: (i) market efficiency; (ii) no risk premiums; and

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1. Frenkel and Levich (1975).

2. Following Bilson (1981).

(iii) zero transactions costs. In our tests, we replace condition (ii) with the more general condition of a constant risk premium.

1.2 Our Empirical Studies

In order to determine whether the markets for exchanges between the U.S. dollar and the Canadian dollar, the French franc, the German mark, the Italian lira, the Japanese yen and the U.K. pound are indeed efficient, we constructed series of forecasting equations for the spot exchange rate and subjected them to a round of tests. These tests were based on the proposition that the exchange markets are efficient — in other words, that if all the relevant known information about events that affect spot exchange rates was being utilized by market participants, that same information would be reflected in forward exchange rates. If so, abstracting from considerations of risk and transactions costs, it follows that the forward rate would be the best available predictor of the future spot rate — no forecasting equation for the future spot rate should be superior to the forward rate alone. Alternatively, if exchange markets are <u>not</u> efficient, information about other variables in addition to the forward exchange rate would prove useful in forecasting the future spot rate. By using these variables, traders could devise simple forward exchange trading strategies that on average would yield profits for a trader who applied them consistently. In our research we have attempted to establish empirically whether such unexploited information is available.

As emphasized above, the tests were joint tests for market efficiency and the absence of time-varying risk premiums and zero transactions costs. In fact, transactions costs in markets for well-traded currencies, embodied in the spread between bid and ask rates, are small and do not vary greatly over time.[3] However, the existence of systematic divergences between the forward rate and the future spot rate is not necessarily evidence of inefficiency since the opportunity provided for

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3. See Appendix B.

increased profits may be available only with an increase in risk exposure. However, it is not possible to determine a priori whether these systematic divergences are an expected compensation for risk or the result of ex ante forecasting errors. Thus, failure to pass our statistical tests could indicate either a lack of market efficiency or the existence of time-varying risk premiums or both.

The tests covered 25 different currency/maturity combinations including at least two for each currency. According to our results, the joint condition[4] of the existence of market efficiency and a constant risk premium is rejected in at least one equation for 21 of the 25 combinations that were tested.[5,6] In most cases, rejection of the joint condition occurred because known movements in interest rate differentials could be used to improve on the forward rate as a forecast of the future spot rate. This implies that relevant information was not fully reflected in the level of the exchange rate. In addition, for the Canadian dollar and the Italian lira, movements in relative price levels (GNE or GDP deflators) do not appear to have been fully taken into account in the exchange market. Rejection of the joint condition leads us to conclude that the exchange market for each currency is inefficient and/or that there are time-varying risk premiums.

We found a fair degree of similarity of coefficients in equations estimated for two-year subperiods, which led us to examine whether an individual could make a profit using simple foreign exchange trading rules.[7] Our results showed that simply buying forward the currency of the country with the highest nominal interest rate would have been a

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4. Technically, the joint condition is the null hypothesis in statistical tests.

5. At a 95 per cent significance level.

6. The four currency/maturity combinations where the joint condition was not rejected were the German mark at one and three months and the U.K. pound at six and twelve months.

7. Transactions costs are not specifically treated in these profit calculations, but even after taking them into account the trading rules would have remained profitable. Appendix B contains a more detailed treatment of these matters.

profitable strategy for almost every currency and maturity, and in most cases the probability of a loss would have been less than 20 per cent after 60 or more forward contracts. Another simple approach, that of buying a currency whose spot value is less than its estimated purchasing-power-parity value,[8] would have been significantly profitable for most maturities of the Canadian dollar, the French franc, the Italian lira and the Japanese yen. More sophisticated methods of prediction, which used estimated equations, were shown to be less profitable, probably because of changes in the coefficients over time.

1.3 Interpretation of the Results

Our findings add to the evidence, surveyed in Chapter 2, that the forward rate is inferior to other predictors of the future spot rate. Taken as a whole, the broad body of evidence for rejection of the speculative efficiency hypothesis is compelling. However, it is impossible in principle to determine whether this finding is due to market inefficiency or variable risk premiums or both.

Our tendency would be to interpret this rejection of the joint hypothesis as evidence of inefficiency in exchange markets. There are two reasons for our conclusion. The first is the lack of success of attempts to relate actual forward rate prediction errors to theoretical determinants of risk premiums.[9] The second is that the rejection of the joint hypothesis in most cases occurred because the known values of variables such as interest rate differentials and relative price levels added significantly to the forward rate in explaining the future spot rate. Since these variables are not plausible measures of currency risk,

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8. The purchasing-power-parity value is derived from relative GDP or GNP deflators and a constant term based on past data.

9. See, for example, J. Frankel (1979b, 1982a, 1982b) and Dooley and Isard (1983) as well as the discussion in Chapter 2. If the empirical divergences between forward and future spot rates are interpreted as risk premiums, then currencies are deemed to switch in their "riskiness" in ways that risk proxies such as net indebtedness and relative stocks of assets cannot explain empirically.

it would appear that information on them was systematically ignored or incompletely incorporated into exchange rate expectations.[10]

When we speak of a risk premium, we mean the difference between the expected future price of foreign currency and its posted forward price expressed in units of domestic currency. The risk premium on foreign currency, when it exists, can be either positive or negative, and will by definition have associated with it a risk premium of opposite sign on the domestic currency. Since domestic and foreign residents therefore cannot mutually obtain a premium on each others' currencies, this premium cannot be related solely to exchange rate variability. However, since risk exposure depends on the supply of claims in a particular currency and the net foreign asset position of the country, equilibrium risk premiums should be related significantly to the relative stocks of claims in different currencies issued by governments and the net foreign asset positions of the countries concerned.[11]

In some empirical studies, risk variables such as those mentioned above, have been found to exert significant influence on spot exchange rates.[12] However, this does not contradict our conclusion that there is unexploited information in exchange markets since the estimated equations incorporating these relative stock variables typically do not exhibit the characteristic that only unexpected changes in the other explanatory variables (relative price levels, interest rates, and so on) cause unexpected changes in the spot exchange rate. In an efficient market this characteristic would be observed.

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10. This does not mean that market participants were irrational in the everyday sense of the word. There are significant costs in processing information. What we show is that the market did not pass a certain standard - that of fully incorporating information on two important economic variables.

11. An intuitive explanation of the risk premium is provided in Appendix F.

12. See R.D. Haas and W.E. Alexander (1979) and W. Branson, H. Halttunen and P. Masson (1977).

1.4 Implications for Policy

The empirical findings on exchange market efficiency impinge directly on the question of whether or not monetary authorities should have an exchange market policy. If the markets were efficient and risk premiums were constant, exchange rates would move in line with the relevant information available to the market. Intervention would then be justified only if the authorities had information on the economic fundamentals that was superior to that held by other actors and if that information could not be published readily.

From this viewpoint, the rejection of the joint condition (market efficiency and constant risk premiums) is important, whether the evidence is interpreted to imply market inefficiency or the existence of a time-varying risk premium. With either interpretation, the case for an active exchange market policy is open.

The first interpretation suggests that exchange markets fail to take full account of information on important economic data. Costs to private traders of processing information and the limited supply of private funds available for long-term currency speculation could be responsible. While private traders put intensive efforts into obtaining and analyzing information that aids in predicting very short-run exchange rate movements, it remains the case that sophisticated models incorporating basic causal variables do not provide significantly better short-run forecasts than some fairly naive formulas, e.g., forecasts based on the recent history of the exchange rate itself. Thus, it is not surprising that from time to time, a change in an exchange rate triggers a "bandwagon" effect. Once underway, the process is self-fulfilling in that extrapolations of recent changes will give relatively accurate forecasts. During such an episode, the market does not give macroeconomic data a weight appropriate to economic policy objectives. Under this interpretation, actions to influence the exchange rate would therefore be a valid component of macroeconomic policy. Intervention could exert an independent effect on the exchange rate if it influenced expectations -- a condition more likely to hold in the short run than in the long run.

The second interpretation also suggests a channel that would allow intervention to have an effect on the exchange rate. According to portfolio theory, the determinants of the risk premium on a given currency include the outstanding stock of claims on the national government concerned and/or the relative stock of net foreign currency indebtedness. Official operations in the foreign exchange market, by changing the composition of private portfolios, would alter risk exposures in the various currencies. An official sale of foreign exchange would thus increase the risk premium on foreign exchange that is required for portfolio equilibrium and hence put downward pressure on the price of foreign exchange. In these circumstances sterilized intervention would be capable of a permanent effect on the exchange rate.

However, as we have pointed out above, research into exchange market efficiency to date has resulted in a distinct lack of success with net foreign asset variables used as proxies for risk. This suggests that intervention unsupported by other policies has likely had little effect on exchange rates in the medium and longer run, and that its effective role is restricted to shorter run objectives such as moderating day-to-day movements in exchange rates.

CHAPTER 2

SURVEY OF EXISTING EMPIRICAL EVIDENCE ON EXCHANGE MARKET EFFICIENCY

2.1 Introduction

In this chapter we go on to provide a survey of the existing empirical evidence on the efficiency of exchange markets (in the sense that exchange rates fully reflect relevant available information).

It is well known that the market rapidly eliminates risk-free gains from covered arbitrage. Covered interest parity between comparable instruments denominated in different currencies has been shown to hold very precisely in Euromarkets (Frenkel and Levich (1975)). While this is a necessary condition for the existence of exchange market efficiency, it is not a sufficient condition, since it says nothing about the existence of unexploited excess returns to speculation. Most of the research on the latter topic investigates whether the forward exchange rate is an optimal predictor of the future spot rate -- in other words, a predictor whose errors are unbiased, show minimum variance and are serially uncorrelated. If these conditions hold, the market is said to exhibit "speculative efficiency".[1]

Rejection of the hypothesis of speculative efficiency need not mean that the market is inefficient and ignores relevant information. The forward rate can diverge systematically from the expected spot rate if risk premiums and transactions costs are large enough to dissuade speculators from closing the gap. The existence of divergences that are biased in one direction or are large with respect to other forecasting models or exhibit some other predictable pattern means the rejection of one or more of the three joint hypotheses embodied in the hypothesis of speculative efficiency. Either transactions costs and/or risk premiums are significant, and/or exchange markets are inefficient.

We belabour this point because the work surveyed provides a

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1. This is the terminology of Bilson (1981).

substantial body of evidence rejecting the idea of speculative efficiency. The forward premium alone is a poor predictor of the change in the spot rate. This finding holds for virtually all the currencies studied and over various time periods.

In the next section we survey the statistical tests on the speculative efficiency hypothesis, and in the final section of the chapter we discuss whether the results of these tests indicate the existence of systematic forecasting errors or just the effects of risk premiums.

2.2 Tests of Speculative Efficiency

There are five types of tests of speculative efficiency: (i) simple descriptive statistics on the accuracy of the forward rate as a forecast of the future spot rate, with the difference $e_t=s_t-f_{t-1}$ regarded as a forecast error;[2] (ii) statistical regressions of the spot rate on the lagged forward rate or of the change in the spot rate on the lagged forward premium (discount); (iii) time series tests of forecast errors to determine whether they contain predictable patterns based on their own past history or other known variables; (iv) comparisons of forecasting accuracy between the forward rate and other prediction methods; and (v) tests on the profitability of trading rules.

Most of the tests use the U.S. dollar as the numéraire, but it seems unlikely that the findings would be substantively different with a different numéraire (Hansen and Hodrick (1981)). The results of particular authors do depend to some extent on the term of the forward rate, but not in a way that would alter materially the conclusions of this survey.

2.2(a) Descriptive statistics of forecast accuracy

Typically, the magnitude and statistical significance of the forecasting error are inferred from the arithmetic mean, the mean absolute

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2. All the variables in this survey are expressed as logarithms. Thus s_t is the log of the spot rate at time t and f_{t-1} is the log of the forward rate at time t-1.

error and the mean squared error. The distribution of the error is further described by the percentage of errors within a given range as well as other measures of dispersion.

The forward rate does not appear to predict the future spot rate very accurately. For example, Levich (1979b) presents data on nine currencies and their three-month forward rates for the 1967-78 period. According to his tests, mean forecast errors were statistically significant for most currencies in most years and even over the entire twelve-year period, mean errors were significantly different from zero. There is, therefore, some evidence of bias although it seems to be small in economic terms over long time periods. If bias represents a risk premium then the premiums evidently are not stable over time: in some years a currency is regarded as risky (the forward price is on average less than the future spot price), but in other years as safe (the forward price is on average greater than the future spot price).

The mean absolute three-month-ahead error found by Levich is approximately 3 per cent for nearly all the major currencies over the 1967-78 period.

In addition, the proportion of variance in the future spot rate explained by the forward rate is low (Dooley and Isard (1979), Frankel (1980) and Agmon and Amihud (1981)). To give a representative example, the coefficient of correlation calculated by Dooley and Isard between the lagged three-month U.S. dollar/German mark forward premium and the change in the spot rate in the 1973-78 period was 0.19.

These results are descriptive measures which summarize certain relevant aspects of the data. Levich (1979a) and others have argued that the findings have ambiguous implications for the notion of exchange market efficiency because of the inability to control for transactions costs, risk premiums and possible shifts of error patterns between subperiods.

2.2(b) Regressions of the spot rate on the lagged forward rate

Equations to test the speculative efficiency hypothesis may be

estimated in terms of the level of the spot rate:[3]

$$s_t = a + bf_{t-1} + u_t \qquad (1)$$

where s_t is the logarithm of the spot rate at time t and f_{t-1} is the logarithm of the one-period forward rate in the previous period and u_t is a residual error.

Or in terms of the change in the spot rate:

$$\Delta s_t = a + b(f_{t-1}-s_{t-1}) + u_t \qquad (2)$$

The "null" hypothesis that the forward rate is an efficient predictor implies a=0, b=1 and a non-serially correlated residual.

Tests with equation (1) tend to accept the null hypothesis (Frenkel (1977), Stockman (1978) and Longworth (1981)), although exceptions are to be found (Frenkel (1977), Frankel (1980) and Baillie, Lippens and McMahon (1981)). However, this test is very weak because predictive power that might be assigned to the lagged spot rate is attributed to the forward rate, the two being closely linked by covered interest arbitrage (Tryon (1979)). Recent research has attempted to apply tests with more discriminatory power.

One step in this direction would be to estimate equation (2) instead of equation (1) in order to see how accurately the change in the spot rate is predicted by the forward premium (Porter (1971), Tryon (1979), Levich (1979b), Agmon and Amihud (1981), Longworth (1981), Cumby and Obstfeld (1982)). The result is that although the null hypothesis is often accepted, the standard error of the coefficient on the forward premium is so large that the coefficient is rarely significantly different from zero; indeed, in many cases it has a perverse (negative) coefficient. Thus, the

3. For simplicity, the equations are written as if the maturity of the forward contract is the same as the periodicity of the data. This is not in fact the case in many of the studies.

forward premium fails to increase the accuracy of a "no-change" forecast. Since this is hardly an exacting comparison, the uniformity of the evidence across different currencies and time periods is very damaging to the hypothesis of speculative efficiency.

Baillie, Lippens and McMahon (1981) tested a bivariate autoregressive model of the 30-day forward rate and the spot rate. Using weekly data they were able to reject the linear restrictions implied by speculative efficiency for all six of the currencies they studied.

2.2(c) Time series tests of the forecast error

A number of authors have tested the forecasting error for serial correlation. The test equations are of the form:

$$e_t = c + d_1 e_{t-1} + d_2 e_{t-2} + \ldots + u_t \qquad (3)$$

The efficiency hypothesis implies that the coefficient c and all d's are zero; if not, there is a predictable pattern in the forecast errors that has been ignored by the market. Cumby and Obstfeld (1981), Dooley and Shafer (1982), Meese and Singleton (1980) and Papadia (1981) found a degree of time dependence inconsistent with the random error that would be associated with an efficient predictor.

The inclusion of other variables known at the time the forecast is made gives the tests more statistical power. Equations such as the following have been estimated using this approach:

$$e_t = c + de_{t-1} + \sum_j d_j e^j_{t-1} + u_t \qquad (4)$$

where e^j_{t-1} is the forecast error for another currency, j.

Geweke and Feige (1979) estimated equation (4) for seven currencies. The null hypothesis was not rejected in single-equation tests for six out of the seven currencies, but was easily rejected on a joint test of all

the equations together. Geweke and Feige attribute this result to the greater power of the latter test.

Procedures have been developed to give asymptotically unbiased estimates of error variance where data periodicity is shorter than contract length.[4] This allows the inclusion of many more data points and thus adds precision in the form of lower standard errors of estimate. Hansen and Hodrick (1980) estimated equations similar to equations (3) and (4) with weekly data on 13-week forward rates. The results for the specification using multi-currency forecasting errors as explanatory variables (equation (4)) rejected the null hypothesis for the Canadian dollar, the German mark and the Swiss franc, but accepted it for the other four currencies tested. The results for the specification using lagged values only of own errors (equation (3)), rejected the null hypothesis only for the mark, suggesting that this may be a weaker test.

2.2(d) Tests of forecasts

A model that fits the data better than the forward rate during the estimation period is not necessarily a better ex ante predictor. There seem to be two approaches to making valid comparisons of forecasting performance. One method would be to use models so naive that the information they embody can be very quickly learned. From this viewpoint, the evidence cited in Section 2.2(c) with respect to the simple autocorrelation of prediction errors indicates that some fairly naive adjustments can improve considerably on the forecasting ability of the forward rate. A second approach would be to use models with a more developed structure and to ensure that model parameters and exogenous variables are derived entirely from data known at the time the forecast is made.

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4. Ordinary least squares estimates of coefficients are unbiased but those of error variance are biased downwards because the error term follows a moving-average process. The effective increase in the number of observations is less than the numerical increase owing to the fact that the forecasting horizons overlap the data points.

A simple generalization of equations (1) and (2) would include the lagged spot rate as an additional regressor with an unconstrained coefficient:

$$s_t = b + cf_{t-1} + ds_{t-1} + u_t \qquad (5)$$

This is equivalent to equation (1) if d=0 and to (2) if d=1-c. The null hypothesis is b=0, c=1, d=0. Longworth (1981) found that the null hypothesis was contradicted in the case of the Canadian dollar. The coefficient d was invariably significantly greater than zero and not significantly different from one, while c was significantly less than unity and not significantly different from zero. Longworth's conclusion that the current spot rate is an unbiased predictor and that the forward rate adds nothing, is consistent with findings for other currencies by Solnik (1978) and with the results of Meese and Rogoff (1981). These results all tend to be robust across different time periods.

Bilson (1981) used generalized least squares with cross-equation restrictions on the coefficients to estimate equations such as our equation (2) jointly for nine exchange rates. Given the additional power that his techniques bring to the test, it is not surprising that Bilson's results also reject the null hypothesis.

Structural models use basic causal variables such as national price levels, interest rate differentials, balance of payments variables, money supplies and net foreign asset variables to explain exchange rates. Boothe [2] found the ex ante forecasts of structural models for the Canadian dollar to be much superior to the forward rate. Meese and Rogoff (1981) presented mixed results, with the forward rate superior for the German mark and the U.K. pound but inferior for the yen. In consequence, a very important issue is unfortunately left unresolved: Boothe's results suggest that information on the fundamentals is not efficiently incorporated into exchange rate expectations, whereas Meese and Rogoff's results are ambiguous on the question. If inefficiencies in exchange rate determination are due to an important extent to inadequate attention by

the market to known movements in underlying variables, then there are serious risks posed for the achievement of macroeconomic objectives -- risks that could possibly be avoided by policy actions.

2.2(e) Profitability of trading rules

Many of the results discussed above imply the existence of simple strategies that would have resulted in positive ex ante returns.[5] If forecast error patterns are stable enough from one period to another, they present exploitable profit opportunities to speculators. Frankel (1980) and Longworth (1979) presented calculations that demonstrated the returns to be large. Dooley and Shafer in 1976 published some simple filter rules that would have yielded net profits for the period 1973-75; in 1982 they found no evidence of declining profitability of identical filters.

Further evidence of unexploited profit opportunities has been provided by Bilson (1981) and Boothe [2]. Their out-of-sample results show that readily available equations and data could have been used to generate expected revenues much in excess of transactions costs. There is no conventional measure of the rate of return to forward speculation, but since the only capital tied up is a margin requirement that may bear a market rate of interest it seems evident that expected returns from the proposed strategies would have been high.

Whereas earlier authors expressed the caveat that apparent inefficiencies within a sample period might not persist long enough to be exploitable, more recent work now suggests that there is a substantial degree of persistence. It has not been established, however, that the forgone expected returns were available with an increase in risk exposure that investors would have willingly accepted.

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5. Speculation may take place in spot as well as forward markets. Because of covered interest parity the two are for present purposes equivalent (Tsiang (1959)).

2.2(f) Market inefficiency or risk premium?

The divergence between the spot rate and the lagged forward rate was defined in the preceding section as a forecasting error since we were concerned with the accuracy of the forward rate itself as a predictor. However, the forward rate may not be equal to the expected spot rate since risk aversion may lead to risk premiums on certain currencies.[6] In general, the forward rate is equal to the expected spot rate plus the risk premium. The forward exchange value of a currency that is particularly risky will on average be below its expected value (Levich (1979a)). This does not represent a forecasting bias but an ex ante return to holding a risky asset.

A majority of the authors have preferred to regard the rejection of speculative efficiency as evidence that risk premiums are significant and time-varying, and have retained the hypothesis that expectations are formed efficiently (e.g., Meese and Singleton (1980), Cumby and Obstfeld (1981), Hansen and Hodrick (1981), and Dooley and Shafer (1982)).

However, the actual patterns of errors are difficult to interpret plausibly in terms of risk premiums. For example, one would infer from the mean errors for 1967-78 tabulated in Levich (1979b) that the German mark, Swiss franc and yen were deemed to be much more risky than the U.K. pound and the Canadian dollar. The statistically sophisticated attempt by Hansen and Hodrick (1981) to derive a latent variable to represent unobserved risk factors produced similar results. The simple explanation of these findings is that the market failed to foresee the rapidity of the increases in the mark, Swiss franc and yen in the sample period. Bilson (1981) points out that the profit/risk ratio of a trading strategy based on his estimated equations appears in any case too large

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6. Transactions costs can account only for a minor part of the variation of the error term. McCormick (1979), using an indirect technique adopted from Frenkel and Levich (1975), estimates the cost of a one-way transaction in the spot market at most as 0.09 per cent. However, the bid-ask spread on well-traded currencies, which is a two-way transaction cost, is typically less than 0.1 per cent. See Appendix B.

to be a normal payment for risk-bearing.

Frankel (1979a) investigated theoretical determinants of risk premiums in a portfolio balance framework. He showed that because of offsetting risks to residents and non-residents, in the absence of government debt, exchange rate risk can be completely diversified and therefore that risk premiums on forward exchange rates can be eliminated even in the presence of risk aversion. Thus, theoretically, currency risk premiums should be related to outstanding stocks of home currency government debt. Extensive econometric experiments by Frankel (1979b, 1982a, 1982b) using this and other theoretically justifiable measures of risk (e.g., exchange rate variance, outstanding net foreign currency liabilities), failed to explain deviations of exchange rate changes from the forward premium. Longworth (1979) found that while certain risk proxies have significant coefficients in equations estimated for the Canadian dollar, the coefficient estimated on the forward premium was significantly different from unity and therefore inconsistent with the market efficiency hypothesis.

Moreover, the variables that often improve the forecasting performance of the forward rate alone -- interest rate differentials, lagged spot rates, relative price level movements -- are not theoretically justifiable risk measures, which means that the results are more indicative of ignored information than of risk factors.

The existence of risk premiums in currency markets cannot be ruled out. The theoretical conditions for the absence of risk premiums represent limiting circumstances, such as perfect currency substitutability and no government debt, that are unlikely to hold in the real world. But there is no evidence that all the systematic divergences between the lagged forward rate and the spot rate can be explained in terms of observable risk variables. We thus feel that the research we have surveyed leads to the conclusion that exchange markets are not efficient.

CHAPTER 3
AN OUTLINE OF THE EMPIRICAL TESTS

3.1 Introduction

As outlined in the introductory chapter, the purpose of this study is to answer a series of questions about the behaviour of exchange rates. As noted in Chapter 1, the primary concern here is the question of whether the exchange market is efficient in the sense that the exchange rate always fully reflects all relevant information. Also, if it appears that the market is not efficient in this sense, what type of information can be identified as being systematically ignored by the market?

The method employed in this paper involved estimating forecasting equations for the spot exchange rate and then subjecting them to a series of tests. The tests that we present are really tests of the joint hypothesis of the existence of market efficiency and the absence of time-varying risk premiums.[1] Thus, rejection of the joint hypothesis could indicate a failure of one condition or the other or of both.[2]

Chapter 3 proceeds as follows. In Section 3.2 we describe the regression equations we used to examine the efficiency hypothesis. Then in Section 3.3, we define a simple trading rule which depends on forecasts from equations similar to those outlined in Section 3.2. This rule is used in later chapters to examine the profitability of speculation. It should be noted that throughout this study we use data that were known when forward contracts were entered into. Appendix A contains details on data construction and other technical material. In Appendix E we argue

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1. The assumption is made implicitly that transactions costs are too small to be important. We base this on the observed bid-ask spreads, which are small. A detailed discussion of transactions costs is found in Appendix B.

2. Note, however, that the presence of a joint hypothesis does not weaken the significance of the tests as support for the efficiency hypothesis in the event that no unexploited information is identified.

that intervention by the authorities should not affect the tests used in this paper.

3.2 Statistical Tests Using Regression Equations

This section describes formal econometric tests of the joint hypothesis of market efficiency and a constant risk premium. The tests were designed to establish whether a superior forecast of the future spot rate can be obtained by using information, including the forward exchange rate, known to all market participants. Since economic theory suggests that, in addition to other variables, contemporaneous interest rate differentials and relative price levels between two countries may influence the exchange rate, the tests performed examined whether information known about these variables[3] when forward contracts are entered into will aid in forecasting exchange rates.[4] If we can discover a set of variables that can be combined to produce a better forecast of the future spot rate than that generated by the forward rate, then this means we can reject the joint hypothesis.

The covered interest parity relationship allows the forward premium to be used as the measure of the interest differential.[5] The relative prices are GNE deflators (theoretically the most appropriate series for a

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3. These variables were chosen because they are readily available for all countries in the G-7 Study. Balance of payments variables could have been used as well.

4. The data used in this study were carefully chosen to ensure that the beginning-of-period spot and forward rates were at the same moment in time and that the forward and future spot rates were matched as to value day. All price indices used would have been known to market participants, i.e., they are preliminary unrevised data with due regard to announcement lags. The data are described in detail in Appendix A.

5. With this measure, it is not necessary to try to select the most comparable instrument from each country, since the market's choice is reflected in the forward premium. The study by Frenkel and Levich (1975) concluded that covered interest arbitrage held in Euromarkets to within transactions costs.

broad measure of purchasing-power parity (ppp)) which are revised only when new figures are released.

Using this information, we then tested the joint hypothesis with regressions of the following form:

$$s_{t+k} - s_t = a + b(f_t^k - s_t) + u_t \tag{1}$$

$$s_{t+k} = a + bf_t^k + cs_t + u_t \tag{2}$$

$$s_{t+k} = a + bf_t^k + c(f_t^1 - s_t) + u_t \tag{3}$$

$$s_{t+k} = a + bf_t^k + c(s_t - ppp_t) + d(f_t^1 - s_t) + u_t \tag{4}$$

$$s_{t+k} = a + b(f_t^k - s_t) + cs_t + d(ppp_t) + u_t \tag{5}$$

where

s_t is the logarithm of the spot price of the U.S. dollar,

s_{t+k} is the logarithm of the spot exchange rate k months ahead,

f_t^k is the logarithm of the k-month forward exchange rate,

ppp_t is the logarithm of the ratio of the country's GNP or GDP deflator to the U.S. GNP deflator, and

u_t is the error term.

If the joint hypothesis of market efficiency and no risk premium holds, then b=1 and a=c=d=0.[6] (If there is a constant risk premium, "a" need not be zero.)

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6. Except in equation (5), where, instead of c=0, the total coefficient on s, c-b, equals zero.

The five equations, which were chosen prior to the commencement of the study to avoid pre-selection bias, have the following interpretations. Equation (1) can be used to examine whether the current forward premium ($f_t - s_t$) is an unbiased predictor of the future change in the spot rate. The second equation can be used to test whether the current spot rate adds anything to the current forward rate in explaining the future spot rate. The third and fourth equations can be used to examine whether the one-month interest rate differential and the known real exchange rate (spot rate adjusted for price levels) help in explaining the future spot rate. Whether or not the current spot rate and the current relative price measure aid in explaining the future spot rate, given the current forward rate, can be examined with the aid of equation (5).

3.3 A Simple Trading Rule

In this section, we discuss how forecasts for each maturity can be combined with a simple trading rule in order to test for the presence of unexploited speculative profits. Forecasts from all five of the above equations will be used in order to avoid pre-selection bias based on the best fit over the total sample. In addition, three strategies suggested by the broad outline of the statistical results will be used.

The five equations were first estimated using approximately three years of data for the various forward rate maturities in order to construct a forecast of the future exchange rate. These forecasts were based only on variables and coefficients that could easily be derived from data known at the time each contract was made. Each month, the equations were re-estimated to take account of the most recent information available. Forecasts were constructed for each maturity. The number of forecasts differs across maturities because of data availability.

In order to speculate profitably in the forward exchange market, the trader must predict correctly the direction of forward rate error. This is done by comparing the forecasted value of the future spot rate to the forward rate. Our trading rule, based on this comparison, can be summarized as follows:

If $S^{*k}_t > F^k_t$, then $Z^k_t = 1.0$ (buy foreign exchange forward);

If $S^{*k}_t < F^k_t$, then $Z^k_t = -1.0$ (sell foreign exchange forward).

Profits can be expressed in the following manner:

$$\pi^k_t = Z^k_t.(S_{t+k} - F^k_t)$$

The forecast of the spot rate k months ahead is denoted by S^{*k}_t; profits from using the k-months-ahead forecast are denoted by π^k_t. The rule is simply to buy one dollar of foreign exchange forward if the predicted future spot rate is greater than the forward rate. In contrast, foreign exchange is sold forward if the future spot price is expected to be lower than the current forward rate. Profits are expressed in terms of return per dollar bet. Since very little, if any, capital is required to make forward purchases or sales of foreign exchange, and any capital that is required may bear the market rate of interest, it is difficult to express profits as a pure rate of return on capital employed.

We used eight different strategies based on the above rule. In the first five strategies, the S^{*k}_t corresponded to the true ex ante predictions derived from equations (1) through (5) respectively. The prediction for strategy (6) was the current spot rate, since one observes empirically that the change in the exchange rate is typically less than that predicted by the forward premium. The prediction for strategy (8) employed a strong version of purchasing-power parity (ppp); the prediction was the current ppp exchange rate calculated with a constant term which is updated monthly. Strategy (7) involved no point prediction of the exchange rate. Rather, it depended on the sign of the one-month interest rate differential:

$$Z_t^k = 1.0 \text{ if } S_t > F_t^1$$

$$Z_t^k = -1.0 \text{ if } S_t < F_t^1$$

Transactions costs were not treated specifically in these profit calculations. In practice, transactions costs are embodied in the spread between bid and ask rates. If the treatment of transactions costs was thought to be a problem, the rule could be modified to make bets only when the expected return was greater than the transactions costs involved.[7]

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7. Boothe (1981) has shown that taking transactions costs into account reduces somewhat the profitability of betting rules based on equations for the Canadian-U.S. exchange rate. However, the reduction in profits is generally less than the transactions costs and the profits remain positive. See Appendix B for more on transactions costs.

CHAPTER 4

EMPIRICAL RESULTS FOR THE CANADIAN DOLLAR/U.S. DOLLAR EXCHANGE RATE

4.1 Introduction

This chapter describes empirical tests of efficiency for the Canadian dollar/U.S. dollar exchange market. The equations used are the five equations outlined in Chapter 3. In Section 4.2, we examine the efficiency hypothesis using these equations for the period June 1970 to December 1981. Section 4.3 uses the same equations for selected two-year subperiods. In Section 4.4, the profitability of the simple trading rule introduced in Chapter 3 is examined. A concluding section briefly summarizes our results. Throughout this chapter we use data for forward exchange rates (one, two, three, six and twelve months), spot exchange rates, and the Canadian and U.S. GNP price deflators that were known when forward contracts were entered into.

4.2 Regression Tests

Equations (1) through (5) of Chapter 3 were estimated from June 1970 to December 1981. The first equation was specified in order to determine whether the forward premium ($f_t^k - s_t$) is an unbiased predictor of the future change in the spot rate $s_{t+k} - s_t$. In this regard, the results found in Table 4.1 indicate that unbiasedness can be rejected only for the one-month forward premium. However, the large standard errors of the coefficients indicate that very precise tests of the joint hypothesis cannot be obtained with this equation. Thus, although unbiasedness cannot be rejected statistically for the other maturities, the estimated coefficient on the forward premium for the two-month and three-month maturities is numerically closer to zero (implying that the future spot rate is unrelated to the forward premium) than to its theoretically expected value of one.

We repeated the test of the joint hypothesis with equation (2) but relaxed the constraint on the beginning-of-period spot rate found in equation (1). The results presented in Table 4.2 show that little additional information is gained in this way. As with equation (1), the joint hypothesis is rejected at a 95 per cent significance level for the one-month maturity only, but note that for the two- and three-month maturities the forward rate adds little to the current spot rate in explaining the future spot rate.

Equation (3) (Table 4.3) includes the forward rate and the short-term interest rate differential proxied by the one-month forward premium, thereby testing the value of including information on the shortest interest differential in addition to the forward rate of the particular maturity. For the one-month forward rate, this is mathematically equivalent to equation (2). For the other terms to maturity, the findings are similar to those for equation (2), with rejection of the joint hypothesis at a 90 per cent level of significance at two months and no rejection at longer maturities.

Equation (4) (Table 4.4) adds the deviation of the spot exchange rate from purchasing-power parity as an explanatory variable.[1] In every case this variable is significantly different from a value of zero, its value under the joint hypothesis. Moreover, the negative coefficient indicates a tendency to return to purchasing-power parity which is not captured by the forward rate. The coefficient on the short-term interest rate is also significantly different from zero in all but the twelve-month forward rate equations and the coefficient on the forward rate is significantly different from one in all but the one-month equation. The results at all maturities strongly reject the joint hypothesis.

Equation (5) (Table 4.5) incorporates the spot rate, the k-period forward premium and the relative price (ppp) term. In this case, the

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1. The test does not require us to specify an absolute value for purchasing-power parity. Changes in the ratio of GNP deflators measure only relative movements in purchasing-power parity over given time periods. Monotonic transformations of the ratio (e.g., rebasing) would give results that differ only in the constant term.

Table 4.1

EQUATION 1: $s_{t+k}-s_t = a + b(f_t^k-s_t)$

k	Period	a	b	S.E.E.
1	1970M7-1981M12	.0005 (.0009)	-.389** (.550)	.01067
2	1970M8-1981M11	.002 (.002)	.066 (.572)	.01556
3	1970M9-1981M10	.003 (.003)	.205 (.597)	.01812
6	1970M12-1981M7	.006 (.006)	1.010 (.717)	.02642
12	1974M1-1981M1	.020 (.011)	1.713 (.815)	.03723

Note: In Tables 4.1 to 4.5, standard errors (adjusted by the Hansen-Hodrick procedure) appear in parentheses and:

* indicates that the coefficient is significantly different from its hypothesized value (b=1; c,d=0) at α =.10.

** indicates that the coefficient is significantly different from its hypothesized value at α =.05.

Table 4.2

EQUATION 2: $s_{t+k} = a + bf_t^k + cs_t$

k	Period	a	b	c	S.E.E.
1	1970M7-1981M12	.002 (.001)	-.431** (.547)	1.412** (.546)	.01061
2	1970M8-1981M11	.003 (.002)	.037* (.572)	.947 (.571)	.01557
3	1970M9-1981M10	.004 (.004)	.163 (.602)	.821 (.599)	.01815
6	1970M12-1981M7	.007 (.007)	1.008 (.784)	-.009 (.722)	.02653
12	1974M1-1981M1	.025 (.018)	1.491 (.965)	-.555 (.893)	.03723

Note: In Tables 4.1 to 4.5, standard errors (adjusted by the Hansen-Hodrick procedure) appear in parentheses and:

* indicates that the coefficient is significantly different from its hypothesized value (b=1; c,d=0) at α =.10.

** indicates that the coefficient is significantly different from its hypothesized value at α =.05.

Table 4.3

EQUATION 3: $s_{t+k} = a + bf_t^k + c(f_t^1 - s_t)$

k	Period	a	b	c	S.E.E.
1	SEE EQUATION (2)				
2	1970M8-1981M11	.003 (.002)	.985 (.023)	-1.909* (1.038)	.01552
3	1970M9-1981M10	.004 (.004)	.986 (.035)	-2.233 (1.523)	.01811
6	1970M12-1981M7	.007 (.007)	.998 (.076)	-.351 (2.951)	.02652
12	1974M1-1981M1	.029 (.018)	.905 (.166)	.172 (5.691)	.03770

Note: In Tables 4.1 to 4.5, standard errors (adjusted by the Hansen-Hodrick procedure) appear in parentheses and:

* indicates that the coefficient is significantly different from its hypothesized value (b=1; c,d=0) at α =.10.

** indicates that the coefficient is significantly different from its hypothesized value at α =.05.

Table 4.4

EQUATION 4: $s_{t+k} = a + bf_t^k + c(s_t - ppp_t) + d(f_t^1 - s_t)$

k	Period	a	b	c	d	S.E.E.
1	1970M6-1981M9	-.003 (.001)	1.021 (.014)	-.115** (.024)	-2.912** (.626)	.00973
2	1970M6-1981M9	-.005 (.002)	1.056** (.024)	-.203** (.042)	-4.737** (1.065)	.01393
3	1970M6-1981M9	-.006 (.003)	1.074** (.035)	-.253** (.058)	-5.753** (1.427)	.01594
6	1970M6-1981M7	-.009 (.006)	1.141** (.065)	-.421** (.101)	-6.632** (2.358)	.02193
12	1974M1-1981M1	-.019 (.019)	1.280* (.156)	-.725** (.199)	-7.691* (3.981)	.03108

Note: In Tables 4.1 to 4.5, standard errors (adjusted by the Hansen-Hodrick procedure) appear in parentheses and:

* indicates that the coefficient is significantly different from its hypothesized value (b=1; c,d=0) at α =.10.

** indicates that the coefficient is significantly different from its hypothesized value at α =.05.

Table 4.5

EQUATION 5: $s_{t+k} = a + b(f_t^k - s_t) + cs_t + d(ppp_t)$

k	Period	a	b	c	d	S.E.E.
1	1970M6-1981M9	-.003	-1.891**	.906**	.115**	.00973
		(.001)	(.621)	(.020)	(.025)	
2	1970M6-1981M9	-.005	-1.506**	.848**	.208**	.01398
		(.002)	(.583)	(.035)	(.043)	
3	1970M6-1981M9	-.007	-1.311**	.801**	.272**	.01579
		(.003)	(.557)	(.048)	(.059)	
6	1970M6-1981M7	-.011	-.656**	.674**	.466**	.02159
		(.006)	(.590)	(.089)	(.105)	
12	1974M1-1981M1	-.002	.045	.497	.802**	.03123
		(.020)	(.727)	(.160)	(.222)	

Note: In Tables 4.1 to 4.5, standard errors (adjusted by the Hansen-Hodrick procedure) appear in parentheses and:

* indicates that the coefficient is significantly different from its hypothesized value (b=1; c,d=0) at $\alpha = .10$.

** indicates that the coefficient is significantly different from its hypothesized value at $\alpha = .05$.

A double asterisk (**) in the c column indicates that c-b, the total coefficient on s, is significantly different from zero at $\alpha = .05$.

joint hypothesis is strongly rejected as the coefficient on the relative price term is significantly greater than zero for all maturities, and the coefficients on the other terms differ significantly from their values under the joint hypothesis in all but the twelve-month equation.

To summarize this section, the joint hypothesis is rejected in the tests for at least the one-month maturity in all equations. Although the simplest equation (1) does not allow the rejection of the hypothesis at other maturities, additional information adds dramatically to the explanatory power of the other equations. The information provided by known relative price levels (ppp) is particularly important in this regard; in equations (4) and (5), the coefficient on ppp is significantly greater than zero and the joint hypothesis is rejected. These rejections of the hypothesis lead us to conclude that the market is speculatively inefficient.

4.3 Regressions for Subperiods

Equations (1) through (5) were also estimated for selected two-year subperiods for each maturity. The results are summarized in Tables C:1 through C:5 of Appendix C and in Table 4.6 below.

Table 4.6 tabulates how closely the estimated coefficients for the subperiods correspond to the signs and/or size of the coefficients for the period as a whole. The conditions listed in the second column of the table are those that hold in the equations for the entire period (Tables 4.1-4.5) for the maturities to the left of the solid line. To illustrate how to read the table, in six out of six subperiods, the point estimate of the coefficient b on the forward rate is negative in equations (1) or (2) for the one-month maturity just as it is in the entire-period equation, whereas under the joint hypothesis it is one. As the table indicates, the violations of the joint hypothesis that occurred over the entire sample period tend to be repeated in the majority of the subperiods. In addition, to the right of the solid line where the results in the subperiods do not duplicate the results of the entire period, the subperiod

Table 4.6

**SUMMARY OF SUBPERIOD ESTIMATION OF EQUATIONS (1) TO (5)
(NUMBER OF SUBPERIODS FOR WHICH GIVEN CONDITION HOLDS)**

Equation	Condition	Maturity (months): 1	2	3	6	12
1	Negative coefficient on forward premium	6/6	5/6*	5/6*	0/5	1/3
2	Negative coefficient on forward rate	6/6	6/6	6/6	4/5	1/3
3	Coefficient on forward rate < 1	6/6	6/6	6/6	5/5	3/3
	Negative coefficient on 1-month forward premium	6/6	6/6	6/6	3/5	2/3
4	Negative coefficient on (s-ppp)	3/6	3/6	4/6*	4/5	2/3
	Negative coefficient on 1-month forward premium	6/6	6/6	4/6*	4/5	2/3
5	Negative coefficient on forward premium	6/6	5/6	4/6*	4/5	3/3
	$0 < c < 1$, where c is coefficient on spot rate	6/6	6/6	6/6	2/5	1/3
	Positive coefficient on ppp	3/6	3/6	4/6*	4/5	2/3

* One of the exceptions is in the first subperiod, a period of fewer than 24 observations.

Note: Maturities to the right of the line are those for which the given condition in the second column did not hold in the equations for the entire period (see Tables 4.1 to 4.5). The given condition held in the total-sample-period equations for all entries to the left of the line.

results often deviate more from the null hypothesis (in a numerical sense) than do the entire-period results.

These results indicate that there may be enough systematic deviation from the joint hypothesis for an individual to make profits based on one or more mechanical trading rules.[2] Such rules or strategies are considered in the next section.

4.4 Profitability of a Simple Trading Rule

In this section, forecasts for each maturity are combined with the simple trading rule introduced in Chapter 3 in order to test for the presence of unexploited speculative profits. These forecasts are from the five equations estimated above. In addition, the three other strategies (6,7,8) outlined in Chapter 3 were also used.

The means and standard deviations of returns per dollar bet for each strategy and maturity are presented in Table 4.7. Three patterns are clear. First, the bets made for the one-, two- and three-month contracts are on average profitable. Second, the six- and twelve-month contracts are usually unprofitable. Third, for the profitable maturities, the strategies that include ppp in the information set are generally more profitable than those that do not. Mean profits for the one-, two- and three-month maturities range from 6 to 34 basis points per dollar bet, but are most often in a close range around 20 points. The standard deviation of returns is generally about ten times the mean. Thus, one cannot say with any confidence that a particular bet will be profitable. However,

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2. Although it is not necessary for the coefficients of equations such as (1) to (5) to be econometrically stable to show that profits can be made, it is interesting to note that with one-month data and division at the middle of the sample period, a Chow test does not reject the equality of coefficients in the two sample halves for equation (1) where the F statistic is 1.50 compared with a critical F of 3.07 at $\alpha = .05$. However, other equations for the one-month forward rate are not stable.

one can make stronger statements about a series of bets.[3]

In order to make statements about the probability of mean profits or losses after a given number of bets, an assumption must be made about the distribution of returns. Returns are assumed to be normally distributed with population parameters given by their sample estimates. Each series of returns is tested using the Kolmogorov-Smirnov test of normality. In no case can the hypothesis that the returns were drawn from a normal population be rejected at the 90 per cent level.

Table 4.8 presents the probability, for each strategy and maturity, that mean profits will be less than or equal to zero after a given number of bets. In each case, the number of bets is arbitrarily chosen to be the same as the number of bets tested above.[4] Thus, this is a calculation of the probability of earning zero or negative mean profits if someone had followed the strategy over the periods defined above, under the assumption that the population of returns using the betting rule is normally distributed with population parameters given by their sample estimates.

Related as they are to the results presented in Table 4.7, it is not surprising that in the case of the one-, two- and three-month maturities, many equations reject the hypothesis of zero or negative profits at an 80 per cent or higher level of confidence. Among the strategies based on equations for the three shortest maturities, the probability of negative profits is lowest for equations (4) and (5) which were the regression equations in which it was easiest to reject the joint hypothesis. For the

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3. For maturities greater than one month, the overlapping nature of the contracts means that returns are not independent. Thus, each series of returns can be divided into a number (equal to the maturity) of independent drawings. Means and deviations for each independent drawing of two- and three-month bets are presented in Table 4.7. Probabilities associated with these independent drawings are presented in Table 4.8.

4. For the two- and three-month bets where independent drawings are considered, the number of bets used in the first calculation is the total number of bets tested above (e.g., 94 for the two-month bets). In the second calculation, it is the number of bets in the particular drawing (e.g., 47 for the two-month bets).

Table 4.7

EXPECTED RETURNS TO FORWARD MARKET SPECULATION

Maturity	Strategy (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	Number of contracts
1-month 1974M1-1981M11*	.00209 (.01379)**	.00057 (.01394)	.00057 (.01394)	.00274 (.01367)	.00274 (.01367)	.00242 (.01369)	.00242 (.01369)	.00173 (.01383)	95
2-month 1974M1-1981M10	.00199 (.01987)	.00195 (.01987)	.00213 (.01985)	.00285 (.01976)	.00260 (.01979)	.00135 (.01970)	.00264 (.01962)	.00177 (.01989)	94
2-month (first drawing)	.00312 (.01982)	.00175 (.01999)	.00175 (.01999)	.00130 (.02003)	.00170 (.02000)	.00179 (.01997)	.00038 (.01978)	.00073 (.02006)	47
2-month (second drawing)	.00086 (.02006)	.00214 (.01996)	.00250 (.01992)	.00441 (.01958)	.00349 (.01977)	.00451 (.01955)	.00489 (.01940)	.00281 (.01988)	47
3-month 1974M1-1981M9	.00234 (.02284)	.00229 (.02285)	.00198 (.02288)	.00311 (.02275)	.00297 (.02277)	.00336 (.02243)	.00279 (.02273)	.00257 (.02281)	93
3-month (first drawing)	.00061 (.02577)	.00088 (.02576)	.00228 (.02567)	.00433 (.02539)	.00433 (.02539)	.00058 (.02571)	-.00132 (.02574)	-.00117 (.02575)	31
3-month (second drawing)	.00202 (.02153)	.00253 (.02186)	.00315 (.02201)	.00307 (.02140)	.00172 (.02156)	.00355 (.02044)	.00595 (.02077)	.00320 (.02138)	31
3-month (third drawing)	.00439 (.02156)	.00253 (.02186)	.00031 (.02201)	.00191 (.02193)	.00286 (.02182)	.00595 (.02114)	.00376 (.02150)	.00570 (.02124)	31
6-month 1974M1-1981M6	-.00324 (.03241)	-.00008 (.03257)	-.00149 (.03254)	-.00679 (.03184)	-.00783 (.03160)	-.00205 (.03250)	-.00123 (.03210)	.00521 (.03209)	90
12-month 1977M1-1980M12	.01942 (.04170)	-.01613 (.04311)	-.01524 (.04344)	-.00191 (.04184)	-.01867 (.04204)	-.00907 (.04516)	-.01151 (.04451)	-.00010 (.04608)	48

* contracting period
** standard deviations are in parentheses

Table 4.8

PROBABILITY OF ZERO OR NEGATIVE MEAN PROFITS

Maturity	Strategy (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	Number of contracts
1-month	.069**	.343	.343	.025*	.025**	.042**	.042**	.113*	95
2-month	.166*	.171*	.149*	.082**	.102*	.060**	.096**	.194*	94
2-month (first drawing)	.064**	.200	.200	.270	.206	.194*	.428	.364	94
2-month (second drawing)	.340	.151*	.113*	.014**	.043**	.012**	.007**	.085**	94
2-month (first drawing)	.140*	.275	.275	.330	.281	.270	.448	.406	47
2-month (second drawing)	.385	.305	.194*	.061**	.113*	.057**	.042**	.169*	47
3-month	.161*	.167*	.202	.094**	.104*	.075**	.119*	.141*	93
3-month (first drawing)	.409	.375	.196*	.050**	.050**	.416	.687	.666	93
3-month (second drawing)	.182*	.059**	.065**	.083**	.220	.047**	.002**	.075**	93
3-month (third drawing)	.025**	.132*	.083**	.199*	.103*	.003**	.046**	.004**	93
3-month (first drawing)	.448	.424	.310	.171*	.171*	.453	.610	.598	31
3-month (second drawing)	.301	.182*	.191*	.212	.328	.169*	.056**	.204	31
3-month (third drawing)	.128*	.293	.212	.314	.232	.059**	.166*	.068**	31
6-month	.829	.509	.668	.978	.991	.722	.640	.060**	90
12-month	.001**	.995	.993	.999	.999	.917	.963	.504	48

* rejects hypothesis at 80%
** rejects hypothesis at 90%

six- and twelve-month maturities, the hypothesis can almost never be rejected at the 80 per cent level. This is in contrast with the strong rejection of the joint hypothesis of market efficiency and a constant risk premium in the regression equations for these maturities. The difference may be due in part to the different time periods since three years of data were lost in calculating coefficients for the initial forecast.

In summary, according to most of the strategies for the one-, two- and three-month maturities, there is evidence of unexploited speculative profits. For these maturities, the addition of the ppp data to the information set increases the size of the mean profit. In contrast, there is only limited evidence of unexploited speculative profits for the six- and twelve-month maturities.

4.5 Summary of the Chapter

The results presented in Section 4.2 are not consistent with the joint hypothesis assuming market efficiency and a constant risk premium. In particular, the joint hypothesis at the one-month maturity is rejected by all the equations. Equations (4) and (5), in which the relative price term enters with a significant coefficient, show rejection of the hypothesis for all five maturities examined. Moreover, as shown in Section 4.3, there is a noticeable consistency across subperiods in the results. For the three shortest maturities (one, two and three months), all strategies described in Section 3.3 can be used to make profits. The probability of losses from a series of 95 contracts following these trading strategies for these three maturities is often less than 10 per cent. Again, these results are not consistent with the joint hypothesis of speculative efficiency. We therefore conclude that the exchange market for the Canadian dollar/U.S. dollar is not efficient and/or there is a time-varying risk premium.

CHAPTER 5
EMPIRICAL RESULTS FOR FIVE OTHER CURRENCIES

5.1 Introduction

Paralleling the previous chapter's empirical tests for the Canadian dollar, in this chapter we apply regression and profitability tests to examine the efficiency hypothesis for the following currencies vis-à-vis the U.S. dollar: the French franc, the German mark, the Italian lira, the Japanese yen, and the U.K. pound. Regression tests are presented in Sections 5.2 and 5.3, and profitability tests in Section 5.4. A concluding section briefly summarizes our results. All the data used were available to market participants at the time they entered into forward contracts.[1]

5.2 Regression Tests for the Entire Period

In this section, regression results for the five equations outlined in Chapter 3 are summarized. The regressions were estimated over the period June 1973 to December 1981 except where the unavailability of data made this impossible (see Appendix A).

The results for equation (1) shown in Table 5.1 indicate that unbiasedness of the forward premium as a predictor of the future change in the spot rate can be rejected in 13 of our 20 cases, including all four maturities for the French franc and Italian lira, three maturities for the Japanese yen and two maturities for the U.K. pound. In only one case is the estimated coefficient on the forward premium positive, but even in that case it is less than one.

The results for equations (2) through (5) are summarized (with those from equation (1)) in Table 5.2.[2] In equation (2), which relaxes the constraint on the beginning-of-period spot rate found in equation (1),

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1. A detailed description of data sources and compilation is provided in Appendix A.

2. Detailed results for these equations are found in Appendix D.

the joint hypothesis is rejected by a χ^2 test (for b=1, c=0) for at least three currencies for each maturity (at α =.10). The results for equation (3), which includes the forward rate and the short-term interest rate differential proxied by the one-month forward premium, also allow rejection of the joint hypothesis for two or three currencies for each maturity at a level of α =.05 (three to five currencies for some maturities if α =.10). Similarly, equations (4) and (5), which introduce a known measure of relative prices, give results which reject the joint hypothesis for two to five currencies for each maturity, depending on the level of significance.[3]

Table 5.3 tabulates the results by currency, rather than by equation. The results indicate that the joint hypothesis can be rejected at α =.05 by a χ^2 test for all maturities in at least three equations (in most cases by all five equations) for the French franc and the Italian lira. All five equations show rejection of the joint hypothesis for the one-month maturity for the U.K. pound. For the Japanese yen the joint hypothesis is rejected in at least one equation for each maturity. In the case of the German mark, rejection of the hypothesis is less frequent, but at least one equation results in rejection (at α =.05) at the six- and twelve-month maturities.

To summarize this section, the joint hypothesis is rejected by at least one equation for at least two of the four maturities considered (at α =.05) for each currency. Rejection is most widespread in the equations for the French franc and the Italian lira. Since rejection of the joint hypothesis for a given currency requires a rejection in only one of the equations for that currency (or, to be more exact, a fraction greater than α of the equations), one must conclude that the foreign exchange market for each currency is inefficient and/or there are time-varying risk premiums.

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3. The introduction of relative prices improves substantially the forecasts for the Italian lira at all maturities.

Table 5.1
EQUATION 1: $s_{t+k} - s_t = a + b(f_t^k - s_t)$

Currency	k	a	b	$\chi^2(1)$	S.E.E.
French franc	1	-.0066	-1.8376**	10.72**	.03234
		(.0038)	(.8756)		
	3	-.0210	-1.7856**	9.82**	.05259
		(.0105)	(.8915)		
	6	-.0432	-2.2249**	10.16**	.07551
		(.0222)	(1.0133)		
	12	-.0922	-2.7608**	9.27**	.11404
		(.0475)	(1.2458)		
German mark	1	.0021	-.5333	1.20	.0333
		(.0051)	(1.4169)		
	3	.0062	-.6706	1.25	.0595
		(.0167)	(1.5198)		
	6	.0157	-.7045	1.34	.0823
		(.0317)	(1.4995)		
	12	.0436	-1.1595	1.34	.1211
		(.0706)	(1.8883)		
Italian lira	1	-.0106	-.4786**	10.02**	.02893
		(.0044)	(.4716)		
	3	-.0340	-.5436**	9.20**	.05339
		(.0138)	(.5097)		
	6	-.0638	-.4523**	5.91**	.07821
		(.0301)	(.6006)		
	12	-.1329	-.6138**	4.43**	.12704
		(.0713)	(.7738)		
Japanese yen	1	.0008	.4803	1.58	.03086
		(.0031)	(.4174)		
	3	.0044	-.2632**	5.63**	.05806
		(.0105)	(.5329)		
	6	.0133	-.6090**	5.30**	.08888
		(.0234)	(.7015)		
	12	.0760	-1.9923**	7.03**	.12324
		(.0469)	(1.1285)		
U.K. pound	1	-.0060	-1.5330**	9.21**	.02919
		(.0037)	(.8434)		
	3	-.0158	-.9899**	4.01**	.05617
		(.0124)	(.9934)		
	6	-.0264	-.6809	2.23	.08281
		(.0267)	(1.1260)		
	12	-.0470	-.4828	1.16	.13397
		(.0631)	(1.3823)		

Standard errors are in parentheses (calculated by Hansen-Hodrick procedure for maturities greater than one month).

* Significantly different from 1 at $\alpha = .10$ (**$\alpha = .05$). (For χ^2 column indicates rejection of joint hypothesis.)

Table 5.2

NUMBER OF CURRENCIES (OUT OF FIVE) IN WHICH JOINT HYPOTHESIS IS REJECTED AT α =.05 (α =.10 in parentheses)
(Based on χ^2 statistics)

Equation	Maturity (months) 1	3	6	12
1	3(3)	4(4)	3(3)	3(3)
2	3(3)	4(4)	1(4)	2(5)
3	3(3)	3(4)	2(3)	2(5)
4	4(4)	2(4)	3(4)	2(5)
5	4(4)	2(3)	2(3)	4(5)

Table 5.3

NUMBER OF EQUATIONS (OUT OF FIVE) IN WHICH THE JOINT HYPOTHESIS IS REJECTED AT α =.05 (α =.10 in parentheses)
(Based on χ^2 statistics)

Currency	Maturity (months) 1	3	6	12
French franc	5(5)	5(5)	5(5)	4(5)
German mark	0(0)	0(1)	1(2)	2(4)
Italian lira	5(5)	5(5)	4(5)	3(5)
Japanese yen	2(2)	2(5)	1(4)	4(5)
U.K. pound	5(5)	3(3)	0(1)	0(4)

5.3 Regressions for Subperiods

Equations (1) through (5) were estimated for each maturity for the following two-year subperiods: 1974-75, 1976-77, 1978-79, and 1980-81. From the list of characteristics (given in Table 5.4) of signs and sizes of coefficients in the overall sample, we have chosen one such characteristic for each of the five equations in order to examine the subperiod results. These are summarized in Tables 5.5 through 5.9. Further information on the subperiod results is given in Appendix D, Tables D:5 and D:6.

In equation (1), the coefficient on the forward premium is negative in all but one case, whereas under the joint hypothesis it should be one. Table 5.5 shows that this coefficient is generally negative in the subperiod results as well, except in the equations for the German mark. The greatest number of negative coefficients are found for the French franc, the U.K. pound and the Italian lira, in that order. Table 5.6 shows that the negative coefficient on the forward rate in equation (2), which is a feature of all the whole-period equations except in the case of the German mark, is also a feature of the majority of subperiod equations for each currency — again with the exception of the mark.

The negative coefficient on the short-term interest rate differential in equation (3), which again is characteristic of all the whole-period equations except those for the German mark, is also a general feature of the subperiod regressions for all currencies other than the mark (see Table 5.7).

In Table 5.8, a negative coefficient on the deviation of the current spot exchange rate from ppp, which is a feature of a number of whole-period equations for the French franc, Italian lira and U.K. pound, also tends to show up in the subperiod equations for those currencies as well as for the German mark. A similar situation occurs with respect to a positive coefficient on the purchasing-power-parity term in equation (5) (Table 5.9), where the franc, lira and pound results for the whole period apply also to the majority of the subperiods.

Table 5.4

NUMBER OF MATURITIES, BY CURRENCY, FOR WHICH CERTAIN CONDITIONS ON COEFFICIENTS HOLD

Equation	Condition	Currency				
		French franc	German mark	Italian lira	Japanese yen	U.K. pound
1	Negative coefficient on forward premium	4	4	4	3	4
2	Negative coefficient on forward rate	4	0	4	1	4
2	Coefficient on forward rate < 1	4	2	4	4	4
3	Coefficient on forward rate < 1	3	4	3	4	4
3	Negative coefficient on 1-month forward premium	4	1	4	4	4
4	Coefficient on forward rate < 1	2	4	0	4	4
4	Negative coefficient on s-ppp	2	0	4	0	2
4	Negative coefficient on 1-month forward premium	4	1	4	4	3
5	Negative coefficient on forward premium	4	0	3	4	3
5	Coefficient on forward premium < 1	4	1	4	4	4
5	Total coefficient on spot rate positive	4	0	4	4	3
5	Positive coefficient on ppp	1	0	4	0	2

Table 5.5

SUMMARY OF EQUATION (1) FOR THE FOUR SUBPERIODS: NUMBER OF CASES IN WHICH COEFFICIENT ON FORWARD PREMIUM IS NEGATIVE NUMERICALLY

	Maturity (months)			
Currency	1	3	6	12
French franc	4	4	4	3
German mark	3	2	1	1
Italian lira	4	3	2	2
Japanese yen	2	3	2	2
U.K. pound	3	3	4	3

Table 5.6

SUMMARY OF EQUATION (2) FOR THE FOUR SUBPERIODS: NUMBER OF CASES IN WHICH COEFFICIENT OF FORWARD RATE IS NEGATIVE NUMERICALLY

	Maturity (months)			
Currency	1	3	6	12
French franc	4	2	3	2
German mark	2	2	1	1
Italian lira	4	3	1	2
Japanese yen	2	3	4	4
U.K. pound	3	3	3	3

Table 5.7

SUMMARY OF EQUATION (3) FOR THE FOUR SUBPERIODS: NUMBER OF CASES IN WHICH COEFFICIENT ON ONE-MONTH FORWARD PREMIUM IS NEGATIVE NUMERICALLY

Currency	Maturity (months)			
	1	3	6	12
French franc	4	4	4	1
German mark	2	1	1	2
Italian lira	4	3	1	2
Japanese yen	3	4	4	4
U.K. pound	3	3	3	3

Table 5.8

SUMMARY OF EQUATION (4) FOR THE FOUR SUBPERIODS: NUMBER OF CASES FOR WHICH DEVIATION OF SPOT RATE FROM PPP IS NEGATIVE NUMERICALLY

Currency	Maturity (months)			
	1	3	6	12
French franc	2	3	2	3
German mark	3	3	3	2
Italian lira	3	4	3	3
Japanese yen	1	0	1	1
U.K. pound	3	3	3	3

Table 5.9

SUMMARY OF EQUATION (5) FOR THE FOUR SUBPERIODS: NUMBER OF CASES IN WHICH COEFFICIENT OF PPP IS POSITIVE NUMERICALLY

Currency	Maturity (months)			
	1	3	6	12
French franc	2	3	3	3
German mark	3	3	3	2
Italian lira	3	4	3	2
Japanese yen	1	1	0	1
U.K. pound	3	4	3	3

These results indicate that over time there may be enough systematic deviation of the estimated coefficients from those consistent with the joint hypothesis for an individual to make a profit using a simple trading rule. Profitability is thus examined in the next section.

5.4 Profitability Using the Simple Trading Rule

In this section, forecasts for each currency and maturity were again combined with the simple trading rule introduced in Chapter 3 in order to test for the presence of unexploited speculative profits. As before, the strategies used were based on predictions from the five equations estimated above plus the three additional strategies (6,7,8) outlined in Chapter 3.

The five equations were first estimated using data for one-, three- and six-month maturities to the end of 1976 in order to construct a forecast of the exchange rate beginning in January 1977. For the twelve-month maturity, the last forecast is made in July 1981 owing to the unavailability of data.

The means and standard deviations of returns per dollar bet for each currency are presented in Table 5.10. A wide range of profits and losses is evident. The country-by-country results are as follows: The average returns for France are generally positive, with the exception of strategies (2) to (5) for the three-month horizon and strategies (3) and (4) for the six-month horizon. The mean returns for the German mark are mostly negative for strategies (1) to (5) and (8), but are uniformly positive using strategies (6) and (7). The average lira returns are most often positive, except for equations (1) to (5) for the six- and twelve-month horizons. The results for the yen are generally positive, with negative mean returns evident for equations (1) to (3) for the three-, six- and twelve-month maturities. The results for the U.K. pound are similar to those for the German mark, with negative returns except for strategies (6) and (7).

Several trends are apparent across currencies. Profits from strategy (7), which is based on the one-month interest differential, are positive for all currencies at all maturities. Strategies (6) and (8), which are based respectively on the sign of the interest differential that matches the maturity of the forward contract and the strong version of ppp, also yield generally profitable forecasts. The exceptions to this finding are the lira in the case of prediction (6), and the mark and the pound in the case of prediction (8). All equations for the one-month maturity show profitability in the case of the franc, lira and the yen. The standard deviations of each currency's returns are generally consistent across equations for each maturity, but range in size from rough equality with, to over ten times the absolute value of the mean.

Table 5.11 presents the probabilities of zero or negative mean returns based on the assumptions that returns are normally distributed[4]

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4. Using the Kolmogorov-Smirnov test of normality, in no case can we reject at the 95% level the hypothesis that the returns for the German mark or Japanese yen were drawn from a normal population. The normality of the vast majority of returns for other currencies also cannot be rejected at the 95 per cent level. Exceptions are those

Table 5.10

MEAN RETURNS TO FORWARD MARKET SPECULATION

Currency	Maturity	Strategy (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	Number of contracts
French franc	1-month 1977M1-1981M12*	.00093 (.00707)**	.00104 (.00705)	.00104 (.00705)	.00071 (.00709)	.00071 (.00709)	.00202 (.00683)	.00202 (.00683)	.00014 (.00713)	60
	3-month 1977M1-1981M12	.00194 (.01192)	-.00153 (.01199)	-.00161 (.01198)	-.00067 (.01207)	-.00171 (.01197)	.00517 (.01091)	.00484 (.01106)	.00231 (.01186)	60
	6-month 1977M1-1981M12	.00408 (.01936)	.00145 (.01974)	-.00021 (.01979)	-.00085 (.01977)	.00145 (.01974)	.00862 (.01778)	.00788 (.01813)	.00582 (.01890)	60
	12-month 1977M1-1981M7	.01259 (.03106)	.00984 (.03206)	.00778 (.03263)	.00693 (.03283)	.00899 (.03231)	.01410 (.03040)	.0357 (.03064)	.00176 (.02842)	55
German mark	1-month 1977M1-1981M12	-.00144 (.01797)	-.00067 (.01802)	-.00067 (.01802)	-.00175 (.01794)	-.00175 (.01794)	.00161 (.01796)	.00161 (.01796)	-.00315 (.01775)	60
	3-month 1977M1-1981M12	.00065 (.03008)	.00480 (.02969)	.00287 (.02967)	-.00494 (.02967)	-.00732 (.02917)	.00553 (.02956)	.00480 (.02969)	-.00378 (.02984)	60
	6-month 1977M1-1981M12	-.00431 (.04592)	.00311 (.04602)	-.00050 (.04613)	-.00775 (.04546)	-.02452 (.03894)	.01081 (.04482)	.00754 (.04550)	-.00386 (.01459)	60
	12-month 1977M1-1981M7	-.03886 (.06621)	-.04715 (.06047)	-.04016 (.06541)	-.05168 (.05658)	-.05168 (.05658)	.00269 (.07346)	.01191 (.07601)	.00662 (.07666)	55
Italian lira ($\times 10^4$)	1-month 1977M1-1981M12	.052 (.290)	.004 (.295)	.004 (.295)	.101 (.277)	.101 (.277)	.023 (.294)	.023 (.294)	.063 (.288)	60
	3-month 1977M1-1981M12	.034 (.525)	-.218 (.478)	-.180 (.493)	.094 (.517)	.086 (.518)	-.004 (.520)	.047 (.505)	.222 (.476)	60
	6-month 1977M1-1981M12	-.066 (.832)	-.424 (.716)	-.146 (.822)	.015 (.835)	-.039 (.834)	-.009 (.835)	.089 (.781)	.342 (.760)	60
	12-month 1977M1-1981M7	.048 (1.443)	-.729 (1.243)	-.596 (1.313)	-.497 (1.354)	-.759 (1.224)	-.088 (1.441)	.083 (1.412)	.609 (1.306)	55

* contracting period
** standard deviations are in parentheses

Table 5.10 (continued)

MEAN RETURNS TO FORWARD MARKET SPECULATION

Currency	Maturity	Strategy (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	Number of contracts
Japanese yen ($x10^4$)	1-month 1977M1-1981M12*	.197 (1.723)**	.009 (1.735)	.009 (1.735)	.464 (1.670)	.464 (1.670)	.133 (1.729)	.133 (1.729)	.038 (1.734)	60
	3-month 1977M1-1981M12	-.363 (3.340)	-.213 (3.354)	-.336 (3.343)	.837 (3.253)	.837 (3.253)	.618 (3.293)	.609 (3.295)	.375 (3.339)	60
	6-month 1977M1-1981M12	-1.519 (5.324)	-1.723 (5.261)	-1.781 (5.241)	.451 (5.522)	.231 (5.536)	1.397 (5.336)	1.327 (5.354)	.910 (5.464)	60
	12-month 1977M1-1981M7	.500 (8.518)	-3.953 (7.549)	-3.798 (7.549)	3.522 (7.763)	-4.254 (7.381)	2.888 (8.021)	2.014 (8.076)	1.790 (8.345)	55
U.K. pound	1-month 1977M1-1981M2	-.00153 (.07048)	-.00368 (.07040)	-.00368 (.07040)	-.00781 (.07006)	-.00781 (.07006)	.01634 (.06855)	.01634 (.06855)	-.00432 (.07037)	60
	3-month 1977M1-1981M12	-.02503 (.12594)	-.00658 (.12826)	.00308 (.12841)	-.06380 (.11117)	-.06648 (.10956)	.05190 (.11730)	.04149 (.12144)	-.00722 (.12824)	60
	6-month 1977M1-1981M12	-.07755 (.17973)	-.07444 (.18106)	-.03344 (.19308)	-.11831 (.15551)	-.12775 (.14772)	.10638 (.16404)	.08667 (.17544)	-.01584 (.19535)	60
	12-month 1977M1-1981M7	-.22719 (.21312)	-.12292 (.28740)	-.08629 (.30068)	-.18395 (.25204)	-.19342 (.24471)	.16129 (.26738)	.10912 (.29302)	-.04208 (.31014)	55

* contracting period
** standard deviations are in parentheses

Table 5.11

PROBABILITY OF ZERO OR NEGATIVE MEAN PROFITS

Currency	Maturity	Strategy (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	Number of contracts
French franc	1-month	.1539*	.1251*	.1251*	.2177	.2177	.0110**	.0110**	.4404	60
	3-month	.1038*	.8389	.8508	.6664	.8665	.0001**	.0003**	.0655**	60
	6-month	.0505**	.2843	.5359	.6331	.2843	.0001**	.0004**	.0087**	60
	12-month	.0013**	.0113**	.0384**	.0582**	.0192**	.0003**	.0005**	.0001**	55
German mark	1-month	.7324	.6149	.6149	.7764	.7764	.2451	.2451	.9147	60
	3-month	.4325	.1093	.2266	.9015	.9738	.0735**	.1056*	.8365	60
	6-month	.7673	.3050	.5319	.9066	.9999	.0307**	.1003*	.9798	60
	12-month	.9399	.9999	.9999	.9999	.9999	.0110**	.1230*	.2611	55
Italian lira	1-month	.0823**	.4562	.4562	.0024**	.0024**	.2709	.2709	.0455**	60
	3-month	.3085	.9999	.9977	.0793**	.0985**	.5239	.2358	.0001**	60
	6-month	.9291	.9999	.9162	.4413	.6406	.5319	.1894*	.0002**	60
	12-month	.4013	.9999	.9996	.9967	.9996	.6736	.3300	.0001**	55
Japanese yen	1-month	.1867*	.4840	.4840	.0158**	.0158**	.3228	.3228	.4325	60
	3-month	.7995	.6879	.7823	.0233**	.0233**	.0606**	.0735**	.0242**	60
	6-month	.9864	.9945	.9957	.2643	.3745	.0287**	.0287**	.0985**	60
	12-month	.3050	.9999	.9999	.9996	.9999	.0047**	.0322**	.0643**	55
U.K. pound	1-month	.5675	.6554	.6554	.8051	.8051	.0322**	.0322**	.6844	60
	3-month	.9382	.6591	.4247	.9999	.9999	.0001**	.0040**	.6700	60
	6-month	.9996	.9993	.9099	.9999	.9999	.0001**	.0001**	.7357	60
	12-month	.9999	.9992	.9830	.9999	.9999	.0001**	.0029**	.8438	55

* rejected at 80%
** rejected at 90%

with population parameters given by their sample estimates, and that samples are the same size as the number of contracts in this study.[5] Of the 160 combinations of currency maturity and prediction, the hypothesis of zero or negative mean profits was rejected at the 80 per cent level 59 times and at the 90 per cent level 50 times. Strategies (6) to (8) rejected the hypothesis most consistently, while (2) and (3) were rarely able to reject it. Rejection of zero or negative mean profits is equivalent to rejecting a joint hypothesis of market efficiency and no risk.

In summary, for the currencies considered in this study, there seems to be considerable evidence for rejecting the joint hypothesis. In a substantial number of cases, the hypothesis of zero or negative mean returns after 60 bets can be rejected at the 90 per cent level. Perhaps surprising is the finding that, on the whole, the simpler strategies ((6) to (8)) are more successful than those predictions that require more econometric analysis.

5.5 Summary of the Chapter

The results presented in Section 5.2 reject the joint hypothesis of market efficiency and a constant risk premium for at least one maturity for every currency. For the French franc and the Italian lira the rejection is particularly strong, with rejection occurring for every maturity and by means of all five equations used. However, there is also sufficient evidence for the rejection of the joint hypothesis as it relates to the exchange markets of the other currencies. Moreover, as

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from predictions (2) through (5) for the three-month maturity and prediction (6) for the twelve-month maturity for the franc; predictions (6) and (7) for all maturities for the lira; and predictions (6) and (7) for the twelve-month maturity for the pound.

5. For maturities greater than one month, the overlapping nature of the contracts means that returns are not independent. Thus, each series of returns can be divided into a number (equal to the maturity) of independent drawings. Table D:7 in Appendix D presents the probabilities of zero or negative mean returns for each independent drawing of the three-month maturity.

shown in Section 5.3, there is a fair consistency across subperiods in the way in which certain coefficients deviate from their values under the joint hypothesis.

These results set the stage for Section 5.4, where a simple strategy based on the short-term interest rate differential was shown to yield positive profits for all maturities for all the currencies studied. Furthermore, for the one-month maturity for the French franc, the Italian lira and the Japanese yen, all eight strategies were profitable. Again these results are not consistent with the joint hypothesis. We therefore conclude that the exchange markets for the five currencies considered vis-à-vis the U.S. dollar are not efficient and/or there are time-varying risk premiums, a conclusion which is consistent with our results for the Canadian dollar in Chapter 4.

APPENDIXES A - F

APPENDIX A

THE DATA

In this Appendix we describe the data used in our study. In addition to data on spot and forward exchange rates, we used GDP or GNE price deflators which were combined to calculate the measure of purchasing-power parity (ppp). Since the sources and data construction for the Canadian dollar differ from those for the other currencies, we will deal with each in turn.

A.1(a) Canadian dollar

Forward rates and beginning-of-contract spot rates were selected from the closing rates on the last Wednesday of each month for value the next business day. The Wednesday rates were chosen in order to minimize the effects of the U.S. dual payments system which was in operation until October 1981 (see M. Levi (1978)). The end-of-contract spot rate (again a closing rate) was selected to correspond to the contract value date of each forward rate in order to calculate correctly the value of any contracts bought or sold at the aforementioned forward rates. The value dates were chosen according to the following rules:

(i) If the next business day following the last Wednesday of month 't' is a given date, the value date of an 'n'-month-forward contract is the same date in month 't+n', except

(ii) If the value date in month 't+n' falls on a weekend or holiday, in which case the value date becomes the next business day, except

(iii) When the next business day is outside month 't+n', in which case the value date becomes the last business day of month 't+n', except

(iv) When the next business day following the last Wednesday of month 't' is the last business day of that month, in which case the value date becomes the last business day of month 't+n'.

The spot rate for that value date is the closing spot rate quoted one business day before. This procedure guarantees that the chosen spot rates correspond exactly to the rates at which forward contracts made the last Wednesday of each month would close. These are actual prices faced by market participants.

The data set includes spot, one-, two-, three- and six-month forward rates which begin in June 1970, when the most recent Canadian flexible exchange rate regime began, and end in December 1981. A twelve-month forward rate series beginning in January 1974 and ending in December 1981 is also included. With such contract data, it is necessary to have an end-of-contract spot rate series that corresponds to each forward rate series, as is obvious when the spot rates are chosen using the criteria outlined above. Spot rate series corresponding to each forward maturity will be of different lengths since a one-month forward contract is concluded the next period, while a twelve-month contract requires twelve periods to mature. Thus, the longer the forward contract, the shorter the corresponding spot rate series.

The ppp measure was constructed using Canadian and U.S. GNE deflators based to 1971=1.0. The data used are the first announcements of these figures. To convert the series from quarterly to monthly frequency, each announcement is recorded in the month it was made, and then repeated until the next announcement was made. These data series begin in June 1970 and end in September 1981.

A.1(b) Other currencies

Monthly observations were selected from daily exchange rate series for France, Italy, Japan, the United Kingdom and West Germany. The selection process is described below. The Data Resources Inc. (DRI)

data base provided daily New York market opening bid and ask quotations for spot and one-, three-, six- and twelve-month forward rates for the period June 1973 to December 1981. The sample was slightly smaller for several forward rates of some countries. All exchange rates were expressed as the number of U.S. dollars per unit of domestic currency, and the bid and ask quotations were averaged to obtain single, mid-point series. Measures of ppp were constructed for each country and are also described below.

Monthly observations were selected from daily spot and forward rate series on a "contract" basis. That is, rates were chosen to correspond to dates at which regular forward contracts opened and closed. Forward rates were chosen on the last Tuesday of each month to minimize "weekend" effects (see M. Levi (1978)). The spot rate corresponding to the contract value date of each forward rate was also selected in order to calculate correctly the value of any contracts bought or sold at the above forward rates. The value dates were chosen according to the following rules:

(i) If the second business day following the last Tuesday of month 't' is a given date, the value date of an 'n'-month-forward contract is the same date in month 't+n', except

(ii) If the value date in month 't+n' falls on a weekend or holiday, in which case the value date becomes the next business day, except

(iii) When the next business day is outside month 't+n', in which case the value date becomes the last business day of month 't+n', except

(iv) When the second business day following the last Tuesday of month 't' is the last business day of that month, in which case the value date becomes the last business day of month 't+n'.

The spot rate for that value date is the spot rate quoted two business days previously. This procedure guarantees that the chosen spot

rates correspond exactly to the rates at which the forward contracts made on the last Tuesday of each month would close and represent actual prices faced by market participants. As with the Canadian data, it is necessary to have an end-of-contract spot rate series that corresponds to each forward rate series.

Measures of ppp for each country were constructed as the ratio of the U.S. GNP deflators to domestic GNP or GDP deflators - GNP deflators were used for Japan and Germany and GDP deflators were used for France, Italy and the United Kingdom. Announced data were used for each country with the exception of France and Italy. That is, each month the latest observation reported in the IMF International Financial Statistics (for the United States, the Survey of Current Business) was recorded. Since deflators are quarterly measures, the same value was recorded for several months until the next quarter's data were announced. Announced data for the French series and part of the Italian series were not readily available, so they were replaced by revised data from the DRI data base which were lagged by four months to account for the announcement lag.

Given that not all data were available from June 1973, the starting points for equations (1) to (5) differ across currencies and maturities. Table A:1 gives the estimation periods for each equation. The twelve-month maturity equations end in July 1981 since 't+12' was then July 1982, the last data we had available.

Table A:1

ESTIMATION PERIODS FOR EQUATIONS

Currency	Equations	Maturity (months) 1	3	6	12
French franc	(1)-(5)	1973M8-1981M12	1973M9-1981M12	1973M9-1981M12	1974M1-1981M7
German mark	(1)-(3)	1973M7-1981M12	1973M7-1981M12	1973M7-1981M12	1973M7-1981M7
	(4)-(5)	1974M7-1981M12	1974M7-1981M12	1974M7-1981M12	1974M7-1981M7
Italian lira	(1)-(5)	1973M6-1981M12	1973M6-1981M12	1973M6-1981M12	1974M1-1981M7
Japanese yen	(1)-(3)	1973M6-1981M12	1973M6-1981M12	1973M6-1981M12	1974M4-1981M7
	(4)-(5)	1974M7-1981M12	1974M7-1981M12	1974M7-1981M12	1974M7-1981M7
U.K. pound	(1)-(3)	1973M6-1981M12	1973M6-1981M12	1973M6-1981M12	1973M6-1981M7
	(4)-(5)	1974M7-1981M12	1974M7-1981M12	1974M7-1981M12	1974M7-1981M7

APPENDIX B

TRANSACTIONS COSTS IN THE PROFITABILITY CALCULATIONS

The costs of making transactions in the exchange market are the spreads between the bid and offer quotes on all rates. Any agent willing to "make" a market for a given currency will quote both a buying (bid) and selling (offer) price. The difference between these prices (bid-offer spread) reflects the charge for performing the exchange. The data used in most exchange rate studies are typically mid-market rates -- the average of bid and offer prices. Thus the total transaction cost for the betting strategy proposed, which involves a purchase or sale of foreign exchange at the forward exchange rate and a subsequent sale or purchase of foreign exchange in the spot market at the time the contract matures, is one half of the forward rate spread plus one half of the pertinent spot rate spread. The DRI data set used for the five currencies other than the Canadian dollar contained information on bid-offer spreads for spot and forward exchange rates, and so actual transactions costs could have been included in the betting strategy and in the calculation of profits.

Table B:1 presents estimates of transactions costs for five currencies and four forward maturities. Columns (1) and (2) give the means and standard deviations of the levels of the spot and forward rates in the monthly, mid-point data set that was used. Columns (3) and (4) give the means and deviations of the bid-offer spreads that correspond to the mid-point levels. In column (5), the spreads are expressed as a percentage of the average level at the relevant rates (i.e., col(5)= 100xcol(3)/col(1)). The final column gives an estimated average cost for the transaction considered in this study, namely, one half of the average spot spread plus one half of the relevant average forward spread reported in column (5).

Percentage spreads in the spot market range from less than 0.05 per cent (for the U.K. pound) to 0.1 per cent (for the Italian lira). Spreads

on forward rates widen as the maturity lengthens, but by proportionally very different amounts depending on the currency. In the case of the pound and the mark for example, the twelve-month forward spread is roughly three times as large as the spot spread. At the other end of the spectrum, the twelve-month forward lira spread is over eight times the spot spread. This is probably evidence of a much thinner twelve-month forward market for the lira relative to that for the pound or the mark.

It is possible to compare some of the figures of Table B:1 with the average spreads estimated by Papadia (1981).[1] Using a selected sample (30 observations) from the period June 1973 to July 1977, he estimated the average percentage three-month forward spreads to be:

French franc	-	.238
German mark	-	.156
Italian lira	-	.369
U.K. pound	-	.095

In some cases these estimates are substantially larger than those presented for the three-month forward rate in column (5) of Table B:1. This may be explained by the relatively small sample used by Papadia, by differing data sources (Papadia used BIS data, while we have used New York market opening rates collected by DRI) or by the different time period examined.

Gross returns from at least one of the three betting strategies (6), (7) and (8) (as found in Table 5.10) are substantially greater than the estimated transactions costs for every currency and maturity. Accounting for transactions costs is not, however, simply a matter of subtracting the

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1. Papadia (1981) gives estimates of transactions costs, which he defines to be the relevant forward bid-offer spread. In the case of the speculative transactions considered in this study, this would represent an overestimate since the forward spread is greater than one half of the forward spread plus one half of the spot spread.

estimated costs from the relevant return. As Boothe (1981)[2] showed, a modified betting strategy might reduce returns by less than the estimated transactions cost by eliminating the marginally unprofitable bets. Explicitly accounting for transactions costs would thus not materially affect the results on efficiency presented here.

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2. Boothe (1981) assumed that transactions costs were equal to 20 basis points for opening and closing (at maturity) three-month forward contracts in the Canadian/U.S. market. This seems to be a significant overstatement of actual costs.

Table B:1

Period	Currency	Maturity	Level		Bid-offer spread			
			Mean	Standard deviation	Mean	Standard deviation	Spread %	Mean transactions cost
			(1)	(2)	(3)	(4)	(5)	(6)
1974M1-1981M12	French franc	Spot	.21672	.01770	.000159	.000078	.0733	
		1-month	.21651	.02004	.000282	.000136	.1302	.000221
		3-month	.21574	.02061	.000316	.000171	.1465	.000238
		6-month	.21459	.02132	.000400	.000222	.1864	.000280
		12-month	.21226	.62220	.000819	.000428	.3850	.000490
1973M7-1981M12	German mark	Spot	.45527	.06476	.000254	.000143	.0558	
		1-month	.45661	.06554	.000400	.000191	.0876	.000327
		3-month	.45749	.06712	.000413	.000208	.0899	.000334
		6-month	.46352	.06922	.000500	.000259	.1079	.000377
		12-month	.47022	.07291	.000712	.000373	.1514	.000483
1974M1-1981M12	Italian lira ($\times 10^4$)	Spot	12.287	2.081	.01260	.00636	.1025	
		1-month	12.201	2.075	.03041	.02117	.2497	.02150
		3-month	12.036	2.068	.03666	.02407	.3046	.02463
		6-month	11.827	2.069	.06364	.05179	.5381	.03812
		12-month	11.469	6.578	.09958	.08174	.8683	.05609
1974M10-1981M12	Japanese yen ($\times 10^4$)	Spot	40.967	6.307	.02781	.01680	.0678	
		1-month	41.106	6.444	.05344	.02462	.1300	.04063
		3-month	41.352	6.699	.05988	.03290	.1448	.04385
		6-month	41.715	7.050	.08816	.03545	.2113	.05799
		12-month	42.353	7.662	.18057	.11732	.4263	.10420
1973M6-1981M12	U.K. pound	Spot	2.08731	.25538	.00101	.00116	.0483	
		1-month	2.08164	.25496	.00147	.00082	.0706	.00124
		3-month	2.07180	.25473	.00153	.00085	.0738	.00127
		6-month	2.05761	.25452	.00159	.00092	.0773	.00130
		12-month	2.03183	.25574	.00232	.00111	.1142	.00166

Exchange rates are expressed in U.S. dollars per unit of other currency.

APPENDIX C

SUBPERIOD RESULTS FOR THE CANADIAN DOLLAR

Table C:1

SUMMARY OF SUBPERIOD RESULTS FOR EQUATION (1): $s_{t+k} - s_t = a + b(f_t^k - s_t)$

CANADIAN DOLLAR

Maturity	Sample period	a	b
1	1979M12 - 1981M11	-.0014	-2.162
	1977M12 - 1979M11	.0005	-2.503
	1975M12 - 1977M11	.0060	-.768
	1973M12 - 1975M11	.0007	-.809
	1971M12 - 1973M11	-.0009	-.837
	1970M7 - 1971M11	-.0008	-.584
2	1979M11 - 1981M10	.0005	-1.100
	1977M11 - 1979M10	.0038	-2.659
	1975M11 - 1977M10	.0180	-1.982
	1973M11 - 1975M10	.0014	-1.238
	1971M11 - 1973M10	-.0013	-.945
	1970M8 - 1971M10	-.0016	.364
3	1979M10 - 1981M9	-.0010	-.627
	1977M10 - 1979M9	.0067	-2.913
	1975M10 - 1977M9	.0027	-2.236
	1973M10 - 1975M9	.0009	-2.044
	1971M10 - 1973M9	-.0011	-.295
	1970M9 - 1971M9	-.0016	1.029
6	1978M12 - 1980M11	.0047	.388
	1976M12 - 1978M11	.0224	2.218
	1974M12 - 1976M11	-.0014	.999
	1972M12 - 1974M11	.0068	1.354
	1970M12 - 1972M11	-.0013	1.691
12	1978M1- 1979M12	.0107	1.040
	1976M1- 1977M12	.0608	.740
	1974M1- 1975M12	.0087	-2.359

Table C:2

SUMMARY OF SUBPERIOD RESULTS FOR EQUATION (2): $s_{t+k} = a + bf_t^k + cs_t$

CANADIAN DOLLAR

Maturity	Sample period	a	b	c
1	1979M12 - 1981M11	-.0504	-1.572	2.265
	1977M12 - 1979M11	.0366	-5.268	6.016
	1975M12 - 1977M11	.0293	-8.243	9.029
	1973M12 - 1975M11	.0003	-.043	.982
	1971M12 - 1973M11	-.0031	-1.846	2.520
	1970M7 - 1971M11	.0052	-2.177	2.685
2	1979M11 - 1981M10	.0843	-.371	.874
	1977M11 - 1979M10	.0718	-5.671	6.192
	1975M11 - 1977M10	.0880	-13.512	13.852
	1973M11 - 1975M10	.0007	-.109	.976
	1971M11 - 1973M10	-.0049	-1.867	2.323
	1970M8 - 1971M10	.0061	-1.074	1.397
3	1979M10 - 1981M9	.0936	-.020	.460
	1977M10 - 1979M9	.0801	-5.999	6.473
	1975M10 - 1977M9	.0542	-5.419	6.134
	1973M10 - 1975M9	.0002	-.625	1.399
	1971M10 - 1973M9	-.0064	-1.274	1.484
	1970M9 - 1971M9	.0117	-.547	.407
6	1978M12 - 1980M11	.1721	-.180	.111
	1976M12 - 1978M11	.0692	-.746	1.352
	1974M12 - 1976M11	.0277	-2.066	1.120
	1972M12 - 1974M11	-.0168	-.918	.594
	1970M12 - 1972M11	-.0015	.530	-.134
12	1978M1 - 1979M12	.190	-1.593	1.351
	1976M1 - 1977M12	.077	.083	.759
	1974M1 - 1975M12	-.002	.260	-.988

Table C:3

SUMMARY OF SUBPERIOD RESULTS FOR EQUATION (3): $s_{t+k} = a + bf_t^k + c(f_t^l - s_t)$

CANADIAN DOLLAR

Maturity	Sample period	a	b	c
2	1979M11 - 1981M10	.0809	.5244	-1.962
	1977M11 - 1979M10	.0742	.5087	-11.136
	1975M11 - 1977M10	.0881	.3569	-26.800
	1973M11 - 1975M10	.0007	.8549	-1.278
	1971M11 - 1973M10	-.0047	.4666	-4.154
	1970M8 - 1971M10	.0063	.3082	-2.901
3	1979M10 - 1981M9	.0914	.4563	-1.541
	1977M10 - 1979M9	.0797	.4801	-12.398
	1975M10 - 1977M9	.0498	.7726	-15.441
	1973M10 - 1975M9	.0002	.6902	-.023
	1971M10 - 1973M9	-.0058	.2352	-3.612
	1970M9 - 1971M9	.0116	-.1443	-1.794
6	1978M12 - 1980M11	.1745	-.0842	.143
	1976M12 - 1978M11	.0886	.4634	-12.834
	1974M12 - 1976M11	.0290	-.9041	-5.735
	1972M12 - 1974M11	-.0137	-.2776	.069
	1970M12 - 1972M11	-.0015	.3660	-1.475
12	1978M1 - 1979M12	.1840	-.1916	-5.027
	1976M1 - 1977M12	.1019	.6313	-12.626
	1974M1 - 1975M12	-.0015	-.7167	4.685

Table C:4

SUMMARY OF SUBPERIOD RESULTS
FOR EQUATION (4): $s_{t+k} = a + bf_t^k + c(s_t - ppp_t) + d(f_t^1 - s_t)$

CANADIAN DOLLAR

Maturity	Sample period	a	b	c	d
1	1979M12 - 1981M11	.034	.820	-.248	-3.13
	1977M12 - 1979M11	.074	.478	.205	-7.68
	1975M12 - 1977M11	-.020	1.118	-.321	-4.61
	1973M12 - 1975M11	-.006	1.005	-.122	-1.42
	1971M12 - 1973M11	-.003	.651	.026	-2.61
	1970M7 - 1971M11	.018	.511	.013	-2.59
2	1979M11 - 1981M10	.070	.625	-2.770	-2.58
	1977M11 - 1979M10	.126	.125	.288	-13.28
	1975M11 - 1977M10	-.006	.991	-.590	-18.28
	1973M11 - 1975M10	-.007	.925	-.166	-.93
	1971M11 - 1973M10	-.004	.431	.035	-4.27
	1970M8 - 1971M10	.004	.401	.115	-1.99
3	1979M10 - 1981M9	.081	.563	-.363	-2.80
	1977M10 - 1979M9	.114	.229	.193	-14.49
	1975M10 - 1977M9	-.049	1.413	-.728	-10.32
	1973M10 - 1975M9	-.012	.812	-.271	.60
	1971M10 - 1973M9	-.006	.260	-.211	-3.55
	1970M9 - 1971M9	.004	.074	.288	.16
6	1978M12 - 1980M11	.157	.055	-.128	.07
	1976M12 - 1978M11	.021	.938	-.428	-10.45
	1974M12 - 1976M11	-.010	.145	-.686	-17.64
	1972M12 - 1974M11	-.023	.130	-.337	-2.78
	1970M12 - 1972M11	-.002	.316	.036	-1.29
12	1978M1 - 1979M12	.229	-.516	.236	-5.65
	1976M1 - 1977M12	.015	1.180	-.644	-11.80
	1974M1 - 1975M12	-.019	-.516	-.344	1.76

Table C:5

SUMMARY OF SUBPERIOD RESULTS FOR EQUATION (5): $s_{t+k} = a + b(f_t^k - s_t) + cs_t + d(ppp_t)$

CANADIAN DOLLAR

Maturity	Sample period	a	b	c	d
1	1979M12 - 1981M11	.034	-2.31	.573	.248
	1977M12 - 1979M11	.074	-7.20	.683	-.205
	1975M12 - 1977M11	-.020	-3.49	.798	.321
	1973M12 - 1975M11	-.006	-.42	.884	.122
	1971M12 - 1973M11	-.003	-1.96	.677	-.026
	1970M7 - 1971M11	.018	-2.08	.524	-.013
2	1979M11 - 1981M10	.072	-.63	.338	.270
	1977M11 - 1979M10	.119	-6.88	.440	-.260
	1975M11 - 1977M10	-.007	-8.78	.367	.610
	1973M11 - 1975M10	-.007	.32	.764	.162
	1971M11 - 1973M10	-.005	-1.99	.454	-.042
	1970M8 - 1971M10	.003	-.35	.586	-.146
3	1979M10 - 1981M9	.078	-.54	.207	.363
	1977M10 - 1979M9	.108	-6.82	.428	-.161
	1975M10 - 1977M9	-.036	-4.09	.543	.742
	1973M10 - 1975M9	-.011	.22	.601	.257
	1971M10 - 1973M9	-.064	-1.24	.212	.013
	1970M9 - 1971M9	.004	.48	.426	-.313
6	1978M12 - 1980M11	.152	-.09	-.053	.135
	1976M12 - 1978M11	-.004	-.33	.586	.530
	1974M12 - 1976M11	-.018	-3.77	-.656	.768
	1972M12 - 1974M11	-.024	-.86	-.246	.329
	1970M12 - 1972M11	-.002	.52	.357	-.102
12	1978M1 - 1979M12	.217	-1.68	-.289	-.150
	1976M1 - 1977M12	.003	-.51	.461	.797
	1974M1 - 1975M12	-.018	-.03	-.872	.315

APPENDIX D

DETAILED RESULTS FOR THE FIVE REMAINING CURRENCIES: FRENCH FRANC, GERMAN MARK, ITALIAN LIRA, JAPANESE YEN, AND THE U.K. POUND

Table D:1

EQUATION 2: $s_{t+k} = a + bf_t^k + cs_t$

Currency	Maturity	a	b	c	$\chi^2(2)$	S.E.E.
French franc	1	.0032	-1.9110*	2.9175**	10.58**	.03250
		(.0596)	(.9862)	(1.0046)		
	3	-.0023	-1.8410*	2.8534**	10.02**	.05285
		(.1534)	(.9614)	(1.0051)		
	6	.0226	-2.3394**	3.3833**	10.78**	.07581
		(.2960)	(1.0735)	(1.1612)		
	12	-.5810	-2.2868*	2.9584**	8.94**	.11218
		(.5640)	(1.2876)	(1.4249)		
German mark	1	-.0246	.4438	.5261	2.37	.0332
		(.0257)	(1.6914)	(1.7071)		
	3	-.1052	.9665	-.8848	2.86	.0582
		(.0771)	(1.7333)	(1.7781)		
	6	-.2306	1.4034	-.6677	3.74	.0775
		(.1293)	(1.5059)	(1.5728)		
	12	-.5448	2.1142	-1.7325	5.61	.1036
		(.2296)	(1.4293)	(1.5338)		
Italian lira	1	.0184	-.4958**	1.5002**	13.45**	.02906
		(.1027)	(.4773)	(.4794)		
	3	-.0280	-.5454**	1.5462**	10.17**	.05365
		(.3251)	(.5104)	(.5196)		
	6	-.0910	-.4475**	1.4434**	5.91**	.07859
		(.6872)	(.6115)	(.6388)		
	12	-.6778	-.5881**	1.5065*	4.62*	.12717
		(1.7995)	(.7747)	(.8456)		
Japanese yen	1	-.2080	.8269	.1354	4.51	.03059
		(.1257)	(.4634)	(.4741)		
	3	-.4331	.1114	.8098	6.08**	.05751
		(.4320)	(.6092)	(.6512)		
	6	-1.0086	.0535	.7630	5.62*	.08646
		(.9156)	(.7589)	(.8533)		
	12	-2.3945	-.0876	.6485	6.34**	.11866
		(1.7477)	(1.2315)	(1.4398)		
U.K. pound	1	-.0220	-1.4159**	2.3778**	12.19**	.02894
		(.0174)	(.8393)	(.84162)		
	3	.0735	-.8389*	1.7179*	6.70**	.05438
		(.0577)	(.9723)	(.9824)		
	6	.1572	-.5152	1.2757	5.00*	.07715
		(.1176)	(1.0689)	(1.0924)		
	12	.4229	-.0486	.4259	5.78*	.11021
		(.2325)	(1.1270)	(1.2048)		

* Test at $\alpha = .10$ (t for b=1; t for c=0; χ^2 for b=1 and c=0)
** Test at $\alpha = .05$

Table D:2

EQUATION 3: $s_{t+k} = a + bf_t^k + c(f_t^1 - s_t)$

Currency	Maturity	a	b	c	$\chi^2(2)$	S.E.E.
French franc	1	.0032	1.0065	-2.9175**	10.75**	.03250
		(.0596)	(.0393)	(1.0046)		
	3	-.0307	.9914	-6.1827**	8.40**	.05459
		(.1560)	(.1027)	(2.4006)		
	6	-.0892	.9611	-10.9342**	7.92**	.08122
		(.3137)	(.2052)	(4.4109)		
	12	-.8639	.4617	-13.4991	6.88**	.12065
		(.6290)	(.4095)	(9.6181)		
German mark	1	-.0246	.9699	-.5261	2.37	.0332
		(.0257)	(.0284)	(1.7070)		
	3	-.1047	.8784	.2186	2.36	.0582
		(.0714)	(.0813)	(4.3789)		
	6	-.2230	.7413*	2.9095	3.81	.0775
		(.1141)	(.1345)	(6.0317)		
	12	-.4285	.4858**	5.3871	4.72*	.1053
		(.1939)	(.2404)	(7.1188)		
Italian lira	1	.0184	1.0043	-1.5002**	10.11**	.02906
		(.1027)	(.0154)	(.4792)		
	3	-.0544	.9966	-4.1832**	18.14**	.05352
		(.3239)	(.0482)	(1.2855)		
	6	-.2009	.9779	-6.1470**	6.58**	.07967
		(.6803)	(.1017)	(2.5709)		
	12	-.9668	.8698	-9.6545*	4.68*	.13082
		(1.7931)	(.2666)	(5.3913)		
Japanese yen	1	-.2080	.9623	-.1354	4.47	.03059
		(.1257)	(.0227)	(.4741)		
	3	-.6388	.8843*	-.8476	5.14*	.05834
		(.3787)	(.0684)	(1.0085)		
	6	-1.3491	.7559*	-1.2322	5.17*	.08725
		(.744)	(.1346)	(1.6939)		
	12	-2.8376	.4827**	-1.1832	6.12**	.14896
		(1.4410)	(.2599)	(7.3979)		
U.K. pound	1	.0221	.9619	-2.3778**	12.25**	.0289
		(.0174)	(.0231)	(.8416)		
	3	.0766	.8761	-4.3914*	6.33**	.0547
		(.0579)	(.0769)	(2.6541)		
	6	.1689	.7413	-4.9297	4.52	.0783
		(.1178)	(.1572)	(5.0512)		
	12	.4406	.3614**	-2.0812	5.78*	.1106
		(.2192)	(.2925)	(8.0541)		

* Test at $\alpha = .10$ (t for b=1; t for c=0; χ^2 for b=1 and c=0)
** Test at $\alpha = .05$

Table D:3

EQUATION 4: $s_{t+k} = a + bf_t^k + c(s_t - ppp_t) + d(f_t^1 - s_t)$

Currency	Maturity	a	b	c	d	$\chi^2(3)$	S.E.E.
French franc	1	.0088	.9856	.0294	-3.2389*	11.38**	.03258
		(.0602)	(.0486)	(.0398)	(1.0967)		
	3	-.0298	.9875	.0054	-6.2407**	8.75**	.05437
		(.1556)	(.1357)	(.1124)	(2.4620)		
	6	-.1042	1.0294	-.0942	-10.0336**	8.47**	.08130
		(.3106)	(.2801)	(.2321)	(4.0612)		
	12	-.7700	1.0792	-.6768	-8.6537	7.49*	.11443
		(.6261)	(.6657)	(.4947)	(7.5691)		
German mark	1	.0053	.9347	.0494	-.5574	3.91	.0323
		(.0415)	(.0499)	(.0585)	(1.9443)		
	3	-.0151	.6760**	.2314	6.6572	6.91*	.0530
		(.1158)	(.1330)	(.1617)	(4.5985)		
	6	.0135	.3728**	.4786*	11.8402	9.37**	.0724
		(.2003)	(.2234)	(.2799)	(6.6178)		
	12	.1628	-.2182**	1.0462*	23.6913	10.81**	.0959
		(.3939)	(.4575)	(.6045)	(10.3489)		
Italian lira	1	-.4912	1.0237	-.0946**	-1.2032**	15.79**	.02851
		(.2499)	(.0174)	(.0425)	(.4883)		
	3	-2.0747	1.0733	-.3753**	-3.1353**	22.76**	.04748
		(.6367)	(.0492)	(.1071)	(1.1657)		
	6	-3.7316	1.1108	-.6549**	-4.5410**	19.79**	.06684
		(1.0809)	(.0929)	(.1809)	(2.0452)		
	12	-6.5620	1.1509	-1.1088**	-7.4866*	19.77**	.10638
		(1.8360)	(.2183)	(.3087)	(3.8172)		
Japanese yen	1	.1159	.9510	.0650	-2.0214	9.60**	.03045
		(.1960)	(.0472)	(.0503)	(1.2614)		
	3	-.0726	.8399	.1367	-3.5811	6.66*	.05617
		(.5863)	(.1427)	(.1588)	(3.6079)		
	6	-.6382	.7037	.1668	-5.8206	6.36*	.08548
		(1.1704)	(.2837)	(.3340)	(6.5693)		
	12	-2.5531	.4820	.0472	-4.1023	7.03*	.11930
		(1.9184)	(.4919)	(.6133)	(9.0255)		
U.K. pound	1	.0072	.9518	.0324	-2.6413**	10.01**	.0296
		(.0244)	(.0324)	(.0387)	(1.0481)		
	3	.1052	.8866	-.0498	-2.5968	4.46	.0571
		(.0792)	(.1097)	(.1245)	(3.1926)		
	6	.2327	.7267	-.0777	-2.1164	3.92	.0814
		(.1529)	(.2235)	(.2436)	(5.6755)		
	12	.5484	.1462**	.0575	3.2897	7.63*	.1074
		(.2442)	(.3801)	(.3983)	(7.5792)		

* Test at $\alpha = .10$ (t for b=1; t for c=0; t for d=0; χ^2 for b=1 and c=d=0)
** Test at $\alpha = .05$

Table D:4

EQUATION 5: $s_{t+k} = a + b(f_t^k - s_t) + cs_t + d(ppp_t)$

Currency	Maturity	a	b	c	d	$\chi^2(3)$	S.E.E.
French franc	1	.0088	-2.2533**	1.0151**	-.0294	11.38**	.03258
		(.0602)	(1.0914)	(.0412)	(.0398)		
	3	.0111	-2.1778**	1.0312**	-.0572	11.27**	.05295
		(.1518)	(1.0736)	(.1044)	(.1117)		
	6	.0238	-2.3571**	1.0456**	-.0052	11.50**	.07620
		(.2962)	(1.1313)	(.2018)	(.2136)		
	12	-.5041	-1.2224	.6180	.5653	9.40**	.10744
		(.5632)	(1.2693)	(.3546)	(.4744)		
German mark	1	.0053	.3773	.9841	-.0494	3.91	.0323
		(.0415)	(1.9166)	(.0341)	(.0585)		
	3	-.0200	2.6777	.9077	.2132	5.87	.0535
		(.1176)	(1.7406)	(.0961)	(.1628)		
	6	-.0053	2.3799	.8481	-.4362	6.99*	.0736
		(.2057)	(1.5712)	(.1668)	(.2878)		
	12	-.0152	3.0441	.7068	-.9045*	8.83**	.12065
		(.3647)	(1.4506)	(.2829)	(.5618)		
Italian lira	1	-.4911	-.1795**	.9290**	.0946**	15.79**	.02851
		(.2499)	(.4888)	(.0370)	(.0425)		
	3	-2.0501	-.0581**	.7018	.3738**	21.66**	.04773
		(.6469)	(.4699)	(.0958)	(.1083)		
	6	-3.6034	.0329*	.4763	.6473**	20.35**	.06589
		(1.0861)	(.4960)	(.1610)	(.1801)		
	12	-6.2554	-.0500*	.0927	1.1023**	21.82**	.10195
		(1.7892)	(.5503)	(.2654)	(.2978)		
Japanese yen	1	.1159	-1.0703*	1.0160	-.0650	9.61**	.03045
		(.1960)	(1.2351)	(.0338)	(.0503)		
	3	-.0678	-.4863	.9778	-.1299	6.50*	.05622
		(.6029)	(1.3666)	(.1039)	(.1608)		
	6	-.6387	-.4651	.8715	-.1462	6.03	.08580
		(1.2358)	(1.5198)	(.2130)	(.3463)		
	12	-2.1259	-.4726	.6065	-.0091	7.39**	.11882
		(1.9806)	(1.3493)	(.3395)	(.6312)		
U.K. pound	1	.0072	-1.6895**	.9842**	-.0324	10.01**	.0296
		(.0244)	(1.0524)	(.0339)	(.0387)		
	3	.0929	-.2847	.8536	.0304	4.69	.0569
		(.0828)	(1.2646)	(.1152)	(.1295)		
	6	.2025	-.0512	.6879	.0330	4.10	.08099
		(.1629)	(1.3440)	(.2268)	(.2550)		
	12	.5706	.6145	.1751	-.0223	7.71*	.1074
		(.2602)	(1.0713)	(.3620)	(.3930)		

* Test at $\alpha = .10$ (t for b=1, t for c-b=0; t for d=0; χ^2 for b=c=1 and d=0)
** Test at $\alpha = .05$

Table D:5

EQUATION (1) FOR SUBPERIODS: $s_{t+k} - s_t = a + b(f_t^k - s_t)$

FRENCH FRANC

Maturity	Sample period	a	b
1	1974-1975	-.0053	-3.0441
		(.0114)	(2.6049)
	1976-1977	-.0076	-1.4031
		(.0106)	(2.3210)
	1978-1979	.0086	-3.6649
		(.0064)	(3.2098)
	1980-1981	-.0172	-2.0300
		(.0067)	(1.3012)
3	1974-1975	-.0206	-2.8812
		(.0247)	(1.9294)
	1976-1977	-.0096	-.3640
		(.0272)	(1.9483)
	1978-1979	.0154	-2.5001
		(.0072)	(1.2425)
	1980-1981	-.0479	-2.1503
		(.0172)	(1.4079)
6	1974-1975	-.0689	-4.3592
		(.0318)	(1.3642)
	1976-1977	-.0466	-1.8005
		(.0517)	(1.9079)
	1978-1979	.0266	-2.7303
		(.0079)	(.8835)
	1980-1981	-.1008	-1.6972
		(.0253)	(1.4994)
12	1974-1975	.1464	-4.4331
		(.0648)	(1.7229)
	1976-1977	-.1025	-3.0053
		(.0883)	(1.8673)
	1978-1979	.0206	-1.1087
		(.0159)	(.8873)
	1980-1981M7	-.2270	1.0734
		(.0168)	(1.4103)

Table D:5 (continued)

EQUATION (1) FOR SUBPERIODS: $s_{t+k} - s_t = a + b(f_t^k - s_t)$

GERMAN MARK

Maturity	Sample period	a	b
1	1974-1975	.0126	-8.0813
		(.0078)	(4.0107)
	1976-1977	.0022	6.0039
		(.0070)	(4.2516)
	1978-1979	.0127	-.7240
		(.0350)	(7.3885)
	1980-1981	-.0083	-1.1002
		(.0134)	(2.7824)
3	1974-1975	.0172	-3.0138
		(.0286)	(4.3307)
	1976-1977	.0049	5.0271
		(.0167)	(3.1495)
	1978-1979	.0711	-3.7723
		(.0551)	(3.8290)
	1980-1981	-.0692	2.7666
		(.0383)	(2.5515)
6	1974-1975	-.0205	2.2317
		(.0426)	(3.3686)
	1976-1977	.0274	2.7129
		(.0163)	(1.5885)
	1978-1979	.1760	-5.1078
		(.0697)	(2.5246)
	1980-1981	-.1046	1.4947
		(.0622)	(2.1547)
12	1974-1975	.0333	-1.4413
		(.0430)	(2.5350)
	1976-1977	.0779	1.9568
		(.0351)	(1.5040)
	1978-1979	.0374	.1630
		(.0822)	(1.6304)
	1980-1981M7	-.2679	2.5315
		(.0659)	(1.2154)

Table D:5 (continued)

EQUATION (1) FOR SUBPERIODS: $s_{t+k} - s_t = a + b(f_t^k - s_t)$

ITALIAN LIRA

Maturity	Sample period	a	b
1	1974-1975	-.0256	-3.4286
		(.0112)	(1.6576)
	1976-1977	-.0128	-.4570
		(.0099)	(.6645)
	1978-1979	-.0004	-1.3485
		(.0090)	(2.2323)
	1980-1981	-.0300	-1.8408
		(.0091)	(1.1311)
3	1974-1975	-.0898	-3.5670
		(.0274)	(1.3280)
	1976-1977	-.0254	-.4038
		(.0235)	(.5470)
	1978-1979	.0196	1.5028
		(.0160)	(1.3644)
	1980-1981	-.0727	-1.0114
		(.0267)	(1.1089)
6	1974-1975	-.2213	-4.8844
		(.0420)	(1.1760)
	1976-1977	-.0082	.0477
		(.0255)	(.3298)
	1978-1979	.0058	-.1382
		(.0227)	(1.0291)
	1980-1981	.4703	8.2751
		(.0500)	(1.1328)
12	1974-1975	-.3387	-3.3702
		(.0915)	(1.4302)
	1976-1977	-.0029	.0084
		(.0535)	(.4106)
	1978-1979	-.0375	-.7569
		(.0409)	(.9240)
	1980-1981M7	-.1596	1.4804
		(.0510)	(.7813)

Table D:5 (continued)

EQUATION (1) FOR SUBPERIODS: $s_{t+k} - s_t = a + b(f_t^k - s_t)$

JAPANESE YEN

Maturity	Sample period	a	b
1	1974-1975	.0007	.6263
		(.0042)	(.4235)
	1976-1977	.0101	3.4188
		(.0038)	(2.3877)
	1978-1979	.0638	-10.6165
		(.0289)	(4.8726)
	1980-1981	.0072	-1.6203
		(.0108)	(1.6383)
3	1974-1975	-.0095	-.3135
		(.0105)	(.4746)
	1976-1977	.0307	2.9071
		(.0073)	(1.7880)
	1978-1979	.1039	-6.7584
		(.0840)	(5.0700)
	1980-1981	.0256	-1.5420
		(.0291)	(1.5695)
6	1974-1975	-.0088	.4293
		(.0089)	(.4883)
	1976-1977	.0672	3.8113
		(.0164)	(1.8657)
	1978-1979	.2503	-8.6647
		(.1565)	(5.1123)
	1980-1981	.0509	-1.9890
		(.0426)	(1.2711)
12	1974-1975	-.0070	.0504
		(.0117)	(.8110)
	1976-1977	.1715	3.0336
		(.0392)	(2.6283)
	1978-1979	.2980	-6.3937
		(.1296)	(2.3595)
	1980-1981M7	.0139	-.9751
		(.0833)	(1.6063)

Table D:5 (continued)

EQUATION (1) FOR SUBPERIODS: $s_{t+k} - s_t = a + b(f_t^k - s_t)$

U.K. POUND

Maturity	Sample period	a	b
1	1974-1975	-.0218	-4.3677
		(.0075)	(1.6098)
	1976-1977	.0048	.9167
		(.0086)	(1.4327)
	1978-1979	-.0071	-9.8077
		(.0119)	(5.9018)
	1980-1981	-.0077	-4.0397
		(.0061)	(1.5834)
3	1974-1975	-.0609	-3.4774
		(.0326)	(2.3082)
	1976-1977	.0077	.8912
		(.0316)	(1.8846)
	1978-1979	.0131	-1.8222
		(.0205)	(3.7631)
	1980-1981	-.0220	-3.2872
		(.0173)	(1.6151)
6	1974-1975	-.0683	-.5201
		(.0697)	(2.5316)
	1976-1977	-.0014	-.0148
		(.0546)	(1.7508)
	1978-1979	.0366	-1.8552
		(.0174)	(1.9905)
	1980-1981	-.0531	-2.3980
		(.0315)	(1.7929)
12	1974-1975	-.3166	-3.8729
		(.1076)	(2.0536)
	1976-1977	.0407	.0606
		(.0711)	(1.3193)
	1978-1979	.6902	-1.8197
		(.0200)	(1.1470)
	1980-1981M7	-.1561	-.2558
		(.0272)	(1.8400)

Table D:6

EQUATIONS (2) and (4) FOR ONE-MONTH MATURITY IN SUBPERIODS

Currency	Equation	Sample period	a	b	c	d
French franc	(2)	1974-1975	-.2878	-.8918	1.6996	
			(.1392)	(2.6566)	(2.6957)	
		1976-1977	-.3887	-.5221	1.2783	
			(.1554)	(2.1244)	(2.1434)	
		1978-1979	-.3592	-.2641	1.0147	
			(.2484)	(3.8745)	(3.9764)	
		1980-1981	.0280	-2.4426	3.4716	
			(.0906)	(1.5585)	(1.5898)	
	(4)	1974-1975	-.1730	1.1693	-.3289	-.5902
			(.2257)	(.4780)	(.4353)	(3.7143)
		1976-1977	-.3079	.5090	.3468	-.8384
			(.1565)	(.1745)	(.2053)	(2.0711)
		1978-1979	-.7466	.1729	.3888	1.7928
			(.3663)	(.4408)	(.2752)	(4.3681)
		1980-1981	.1375	1.6909	-.7444	-3.4253
			(.1270)	(.5472)	(.6120)	(1.5724)
German mark	(2)	1974-1975	-.2707	-9.9641	10.6540	
			(.0811)	(3.3032)	(3.2899)	
		1976-1977	-.0090	6.2833	-5.2957	
			(.0775)	(4.7534)	(4.7883)	
		1978-1979	-.1373	4.0593	-3.2572	
			(.1059)	(7.8712)	(7.9258)	
		1980-1981	-.0449	-1.5026	2.4485	
			(.0437)	(2.8339)	(2.8246)	
	(4)	1974-1975	-.3812	-.7780	-.1706	-15.4297
			(.1740)	(.6329)	(.5600)	(7.3804)
		1976-1977	-.4558	1.5740	-.8284	2.4494
			(.2748)	(.3567)	(.4906)	(4.8908)
		1978-1979	-.9902	1.1867	-1.0856	3.5683
			(.2501)	(.1495)	(.2998)	(6.3083)
		1980-1981	-.0291	.9004	.0409	-2.4579
			(.2452)	(.6957)	(.6253)	(2.8976)

Table D:6 (continued)

EQUATIONS (2) and (4) FOR ONE-MONTH MATURITY IN SUBPERIODS

Currency	Equation	Sample period	a	b	c	d
Italian lira	(2)	1974-1975	-.6263	-3.6326	4.5401	
			(1.1345)	(1.7259)	(1.6989)	
		1976-1977	-2.8039	-.0410	.6272	
			(.5408)	(.4586)	(.4793)	
		1978-1979	-2.7707	-.5043	1.0923	
			(1.2131)	(2.1036)	(2.1466)	
		1980-1981	-.1019	-1.8156	2.8052	
			(.2782)	(1.1607)	(1.1652)	
	(4)	1974-1975	-.7224	.9373	-.0434	-4.1577
			(1.1946)	(.1985)	(.1278)	(2.0350)
		1976-1977	-3.5960	.5612	-.0921	-.1664
			(.9115)	(.0831)	(.0855)	(.6412)
		1978-1979	-3.4152	.4243	.0668	-.4185
			(1.4402)	(.2660)	(.0797)	(2.2697)
		1980-1981	-.6895	1.0682	-.1686	-2.8650
			(.5838)	(.0788)	(.1454)	(1.1570)
Japanese yen	(2)	1974-1975	-1.0336	.4156	.4024	
			(.9086)	(.4596)	(.4215)	
		1976-1977	.1743	2.4164	-1.3873	
			(.5452)	(4.0027)	(4.0799)	
		1978-1979	-.0384	-9.9526	10.9343	
			(.6637)	(6.1811)	(6.2531)	
		1980-1981	-1.0956	-1.5895	2.3855	
			(.6068)	(1.5585)	(1.5636)	
	(4)	1974-1975	-2.1831	.2416	.3595	-.6384
			(1.1882)	(.2992)	(.1803)	(1.6044)
		1976-1977	.1545	.9053	.1146	1.6555
			(.5671)	(.6333)	(.5874)	(4.3502)
		1978-1979	-.3758	.4160	.4791	-5.6146
			(.5842)	(.2207)	(.1649)	(5.7275)
		1980-1981	-2.7908	1.4757	-.9171	-3.2506
			(1.0104)	(.3514)	(.4526)	(1.5209)

Table D:6 (continued)

EQUATIONS (2) and (4) FOR ONE-MONTH MATURITY IN SUBPERIODS

Currency	Equation	Sample period	a	b	c	d
U.K. pound	(2)	1974-1975	-.0382	-4.4240	5.4435	
			(.0545)	(1.6548)	(1.6634)	
		1976-1977	.1403	2.4236	-1.6492	
			(.0598)	(1.4693)	(1.5162)	
		1978-1979	.0140	-10.1002	11.0693	
			(.0799)	(6.1273)	(6.1080)	
		1980-1981	.0712	-5.1905	6.0878	
			(.0488)	(1.6826)	(1.6572)	
	(4)	1974-1975	.0595	1.0142	-.1474	-2.8458
			(.0802)	(.0702)	(.1216)	(2.4740)
		1976-1977	-.0539	.5841	.4977	-3.0236
			(.0864)	(.1091)	(.1769)	(2.1183)
		1978-1979	.0745	.9758	-.0978	-12.3327
			(.1090)	(.1161)	(.1189)	(6.3438)
		1980-1981	.0992	1.0496	-.1828	-5.1310
			(.0566)	(.1680)	(.1868)	(1.9252)

Table D:7

PROBABILITY OF ZERO OR NEGATIVE MEAN PROFITS AT THREE-MONTH MATURITY

Currency	Drawing	n*	Strategy 1	2	3	4	5	6	7	8
French franc	1	20	.1635	.7517	.7764	.6293	.7764	.0039	.0039	.2843
		60	(.0446)	(.8790)	(.9066)	(.7190)	(.9066)	(.0001)	(.0001)	(.1611)
	2	20	.3050	.7580	.7580	.6217	.6217	.0150	.0475	.1841
		60	(.1867)	(.8869)	(.8869)	(.7054)	(.7054)	(.0001)	(.0019)	(.0594)
	3	20	.2578	.6255	.6255	.5359	.7823	.0630	.0630	.1335
		60	(.1292)	(.7088)	(.7088)	(.5636)	(.9162)	(.0041)	(.0041)	(.0274)
German mark	1	20	.2776	.2296	.2296	.8238	.8238	.2296	.2296	.6368
		60	(.1562)	(.1003)	(.1003)	(.9463)	(.9463)	(.1003)	(.1003)	(.7324)
	2	20	.6331	.2877	.2877	.7054	.9441	.2236	.2877	.6103
		60	(.7224)	(.1660)	(.1660)	(.8264)	(.9971)	(.0951)	(.1660)	(.6844)
	3	20	.5040	.2033	.5160	.7580	.8051	.1611	.2033	.8577
		60	(.5120)	(.0749)	(.5279)	(.8888)	(.9306)	(.0636)	(.0749)	(.9678)
Italian lira	1	20	.4681	.9871	.9850	.3336	.1977	.4920	.4920	.0016
		60	(.4483)	(.9999)	(.9999)	(.2296)	(.0708)	(.4880)	(.4880)	(.0001)
	2	20	.2676	.9803	.8708	.0901	.0901	.4207	.2206	.0052
		60	(.1423)	(.9998)	(.9750)	(.0102)	(.0102)	(.3632)	(.0918)	(.0006)
	3	20	.4286	.9608	.9394	.2451	.4960	.6255	.3050	.1539
		60	(.3745)	(.9989)	(.9963)	(.1151)	(.4247)	(.7123)	(.1867)	(.0392)
Japanese yen	1	20	.7123	.7123	.8485	.3897	.3897	.1210	.1210	.2810
		60	(.8315)	(.8315)	(.9633)	(.3121)	(.3121)	(.0212)	(.0212)	(.1587)
	2	20	.8413	.5199	.5199	.0516	.0516	.3050	.3050	.3105
		60	(.9573)	(.5319)	(.5319)	(.0023)	(.0023)	(.1867)	(.1867)	(.1841)
	3	20	.4602	.5793	.5793	.0455	.0455	.2206	.2327	.3520
		60	(.4286)	(.6331)	(.6331)	(.0018)	(.0018)	(.0918)	(.1020)	(.2578)
U.K. pound	1	20	.8413	.3192	.2546	.9441	.9441	.0307	.0307	.6517
		60	(.9582)	(.2090)	(.1721)	(.9970)	(.9970)	(.0006)	(.0006)	(.7486)
	2	20	.7123	.8665	.6844	.9986	.9998	.0094	.0094	.4761
		60	(.8340)	(.9726)	(.7454)	(.9999)	(.9999)	(.0001)	(.0001)	(.4562)
	3	20	.8577	.6026	.5359	.9998	.9998	.0446	.3446	.6554
		60	(.9678)	(.6772)	(.5636)	(.9999)	(.9999)	(.0016)	(.2451)	(.7549)

* Number of contracts on which probability calculations based

APPENDIX E

INTERVENTION VARIABLES AND TESTS OF EFFICIENCY

If the exchange market is efficient, then spot and forward exchange rates must reflect, among other things, known past intervention and rationally forecasted future intervention. Intervention thus cannot by itself render a market inefficient. Intervention can, however, affect the interpretation of statistical tests for efficiency in a number of ways.

The first, and most obvious channel of influence is that past intervention changes the relative asset stocks held by the private sector and therefore, in the presence of risk aversion, may influence the expected risk premium at the beginning of a period. This does not affect rejection of the joint hypothesis but may influence the interpretation of why the joint hypothesis is rejected.

The second way in which intervention can affect the interpretation of tests occurs when a large intervention, which is both unexpected ex ante and unexplainable by an existing policy rule which related the amount of intervention to the size of the contemporaneous exchange rate change, causes a large shift away from unity in the coefficient of the forward rate in equations such as (1) through (5) of Chapter 3. In such a case, one should not interpret this bias as a rejection of efficiency, because there would be no way ex ante or ex post for traders to take advantage of the information. The results from mechanical trading rules, such as those proposed in Chapter 3 of this study, would show this clearly.

The problem treated in the above paragraph cannot be dealt with by including contemporaneous intervention in the regression equation since such intervention will nearly always be correlated with some information that the market did not have when it made its forecasts.[1] However, it should be noted that observations associated with instances of major interventions that were unexplained by previous policy rules could be

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1. Indeed if intervention is of the leaning-against-the-wind type (as suggested by the results of Artus (1976), Quirk (1977) and Longworth (1980)), then since nearly all exchange rate movements are unexpected, intervention will be highly correlated with "news" which moves the exchange rate.

dropped in performing regression tests for bias of the forward rate.

The econometric problems one encounters when attempting to include contemporaneous intervention can be illustrated by the following simple model:

$$\Delta s_t = bp_t + cX_t + u_t \tag{1}$$

$$X_t = k\Delta s_t + v_t \tag{2}$$

where

$\Delta s_t = s_t - s_{t-1}$;

$p_t = f^1_{t-1} - s_{t-1}$ is the beginning-of-period forward premium;

X_t is intervention from time t+1 to time t; and

u_t and v_t are white noise error terms.

The reduced form of the system is

$$X = \left[\frac{kb}{1-kc}\right]p + \left[\frac{k}{1-kc}\right]u + \left[\frac{v}{1-kc}\right] \tag{3}$$

$$\Delta s = \left[\frac{b}{1-ck}\right]p + \left[\frac{u}{1-kc}\right] + \left[\frac{cv}{1-kc}\right] \tag{4}$$

If Δs is regressed on p and X (equation (1)), the ordinary least squares estimates of b and c are:

$$\hat{b}_{ols} = \frac{(X'X)(\Delta s'p)-(X'p)(\Delta s'X)}{(p'p)(X'X)-(X'p)^2} \tag{5}$$

$$\hat{c}_{ols} = \frac{(p'p)(\Delta s'X)-(X'p)(\Delta s'p)}{(p'p)(X'X)-(X'p)^2} \tag{6}$$

It can be shown that if $\frac{p'p}{n}$ converges to a matrix, and if u and v (and p and v) are uncorrelated in the limit, then

$$\text{plim} \quad \hat{b}_{ols} = \frac{b\sigma_v^2}{k\sigma_u^2 + \sigma_v^2} \tag{7}$$

and

$$\text{plim} \quad \hat{c}_{ols} = \left[\frac{k\sigma_u^2 + c\sigma_v^2}{k^2\sigma_u^2 + \sigma_v^2}\right] \tag{8}$$

In general, these are not equal to b and c, so the OLS estimates are not consistent. (The case k=0, which gives consistency, is the case where intervention does not respond to the current change in the exchange rate.) When intervention in truth has no effect on the exchange rate, c=0, and

$$\text{plim} \quad \hat{b}_{ols} = \frac{b\sigma_v^2}{k\sigma_u^2 + \sigma_v^2} \tag{9}$$

$$\text{plim} \quad \hat{c}_{ols} = \frac{1}{k + \frac{\sigma_v^2}{k\sigma_u^2}} \tag{10}$$

These results imply that if X_t is measured in sales of foreign reserves and if s_t is the log of the price of foreign exchange implying that k is positive for a leaning-against-the-wind rule, $\hat{b}_{ols}$ is downward biased and that $\hat{c}_{ols}$ will tend to be positive. In the example given, there is only one exogenous variable. The system is therefore under-identified, so no consistent estimator can be found.

APPENDIX F

AN INTUITIVE EXPLANATION OF THE DETERMINATION OF THE RISK PREMIUM

The risk premium on a foreign currency is the difference between the expected future price of foreign currency and its posted forward price, both prices being expressed in units of domestic currency. The risk premium on foreign currency, when it exists, can be either positive or negative, and will by definition have associated with it a risk premium of opposite sign (i.e., a "discount") on the domestic currency expressed in units of foreign exchange. In the case where the premium on foreign exchange is positive, domestic investors can expect that holding an uncovered foreign exchange position will yield a profit over and above what could be obtained by "locking in" the domestic currency value of their foreign currency holdings at the prevailing forward exchange rate. At the same time, foreign investors who take a long position in the domestic currency can expect a loss compared to what they could obtain by locking in the foreign currency value of their domestic currency position by selling it forward at the prevailing forward market rate. Were a positive risk premium to exist at a point of equilibrium, it could be said that domestic investors were requiring a premium in order to hold a long foreign position while foreign investors were prepared to accept domestic currency at a discount. In this situation one might say that the foreign currency was considered the "riskier" of the two.

Given the foregoing definition of the risk premium, the variance of prices, often used to describe risk in other financial markets, is not by itself an adequate explanation of risk premiums in the exchange market.

However, as demonstrated below, the unpredictable nature of the exchange rate cannot be the sole cause of the risk premium because (i) it cannot determine the sign (direction) of the premium; and (ii) an investor will always have the option of offsetting the effects of unpredictable exchange rate movements by using the forward exchange market.

In the case where a positive premium on the foreign currency exists, for example, there is an incentive for domestic residents to hold an uncovered foreign currency position since they expect to profit from doing so. It is less obvious why in these circumstances a foreign resident who had a need for domestic currency would maintain a long position in it, since he could always reduce his expected losses by covering his domestic currency position by selling it in the forward market at the prevailing forward price. In fact the response to the incentive to conduct forward sales would tend to put upward pressure on the forward price of domestic currency measured in units of foreign exchange. If the number of investors wishing to cover their positions was sufficiently large and there were no impediments to their doing so, the forward price could be driven up to the level of the expected future price, thereby eliminating the risk premium. Thus, provided that all investors who wish to do so can cover their foreign exchange holdings in the forward market, neither the degree of variability of the exchange rate nor its causes can be cited as sole determinants of the risk premium, since they are not sufficient reasons to explain its existence.

The factors that determine the risk premium therefore can be summarized as those which would prevent there being sufficient upward pressure on the forward exchange rate to close the gap between the expected future exchange rate and the forward rate. Among those factors that could be cited are the relative supplies of and demands for domestic and foreign assets and liabilities. Theoretical research using portfolio models (Frankel, (1979a)) indicates that an increase in the world supply of government bonds denominated in foreign currency (for example, to finance budget deficits) is likely to increase the risk premium on that currency. In the context of other models where political and default risks play a role, an increase in the net foreign liabilities of a country (through current account deficits) may increase the risk premium on its currency.

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